DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY CALIF 93940

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A Q-GERT APPROACH TO A REQUISITION PROCESSING SIMULATION AT NAVAL SUPPLY CENTER SAN DIEGO

by

Bruce R. Faurie

September 1980

Thesis Advisor: F. R. Richards

Approved for public release; distribution unlimited.

T197469

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIF. 93940

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
A Q-GERT Approach to a Requisition Processing Simulation at Naval Supply Center San Diego

5. TYPE OF REPORT & PERIOD COVERED
Master's Thesis; September 1980

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Bruce R. Faurie

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93940

12. REPORT DATE
September 1980

13. NUMBER OF PAGES
214

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Q-GERT
Requisition processing simulation
Naval Supply Center San Diego

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A model is developed to simulate various aspects of Naval Supply Center requisition processing. The model is based on the Q-GERT simulation language. Q-GERT was selected because of the likelihood that existing stock point personnel could be easily trained to model stock point requisition throughput with a language that is coded directly from a visual display of the processes being

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
(Page 1) S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

#20 - ABSTRACT - (CONTINUED)

simulated. This thesis introduces the basic Q-GERT concepts and develops the necessary symbology to model the NSC San Diego NSN requisition throughput procedure.

Approved for public release; distribution unlimited.

A Q-GERT Approach to a Requisition Processing Simulation at Naval Supply Center San Diego

by

Bruce R. Faurie
Lieutenant Commander, Supply Corps, United States Navy
B.A., Miami University, 1971

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL

September 1980

ABSTRACT

A model is developed to simulate various aspects of Naval Supply Center requisition processing. The model is based on the Q-GERT simulation language. Q-GERT was selected because of the likelihood that existing stock point personnel could be easily trained to model stock point requisition throughput with a language that is coded directly from a visual display of the processes being simulated. This thesis introduces the basic Q-GERT concepts and develops the necessary symbology to model the NSC San Diego NSN requisition throughput procedure.

TABLE OF CONTENTS

I. INTRODUCTION ---------- 8

II. THE SIMPLIFIED MODEL ----------17

III. DISCUSSION OF THE SIMPLIFIED MODEL ----------24

IV. ADDITIONAL BASIC Q-GERT CONCEPTS ----------27

A. THE REGULAR NODE ----------27

B. BALKING AT Q-NODES ----------30

C. BLOCKING SERVICE ACTIVITIES ----------32

D. PROBABILISTIC BRANCHING ----------32

E. Q-GERT INPUT CARD OVERVIEW ----------33

V. NSC SAN DIEGO DEMAND PROCESSING DISCUSSION ----------35

A. REQUISITION CATEGORIZATION ----------35

B. QUICK PIC AND BEARERS (WALK-THROUGHS) ----------37

C. DEMAND PROCESSING PROCEDURES ----------39

D. NSC SAN DIEGO DEMAND DATA ANALYSIS ----------42

E. EXCEPTIONS AND WAREHOUSE REFUSALS ----------46

F. MODELING CONSIDERATIONS ----------49

VI. MODELING THE ARRIVAL AND CATEGORIZATION OF REQUISITIONS ----------52

A. ATTRIBUTE ASSIGNMENT ----------52

B. CONDITIONAL BRANCHING ----------55

C. THE AUTODIN ARRIVAL AND CATEGORIZATION PROCESS ---57

D. THE POE ARRIVAL AND CATEGORIZATION PROCESS -------67

VII. CUSTOMER SERVICES AND DPD KEYPUNCH ----------73

A. Q-GERT RESOURCES ----------73

B. CUSTOMER SERVICES ---------- 81

C. DATA PROCESSING DEPARTMENT KEYPUNCH ---------- 99

VIII. DATA PROCESSING DEPARTMENT BATCH PROCESSING AND LOTTING ----------105

A. DPD FUNCTIONAL OVERVIEW ----------105

B. DPD Q-GERT SYMBOLOGY ----------112

IX. ISSUE, PACKING, MARKING, AND LOCAL DELIVERY ----------120

A. DATA CONSIDERATIONS ----------120

B. BROADWAY BULK MATERIAL PROCESSING ----------122

C. BROADWAY BIN MATERIAL PROCESSING ----------130

D. NATIONAL CITY MATERIAL PROCESSING ----------145

E. LOCAL DELIVERY ----------152

F. STATISTICS COLLECTION ----------160

G. POTENTIAL PROCEDURAL CHANGES ----------162

X. NETWORK TIMING ----------165

A. TIMING OVERVIEW ----------165

B. WEEKLY MASTER AND RESOURCE INITIALIZATION --------166

C. PERSONNEL RESOURCE CONTROL ----------172

D. LOCAL DELIVERY AND MESSENGER SCHEDULING ----------176

E. ADP RESOURCE CONTROL AND BATCH PROCESSING --------181

F. AUTODIN AND POE ARRIVAL PATTERNS ----------185

XI. SUMMARY AND CONCLUSION ----------195

A. MODEL VALIDATION ----------195

B. SUGGESTED AREAS OF ANALYSIS ----------201

C. CONCLUSION ----------203

APPENDIX A: Q-GERT DISTRIBUTION AND FUNCTION TYPES WITH REQUIRED PARAMETER VALUES ----------205

APPENDIX B: NSC SAN DIEGO DAILY DEMAND DATA - OCTOBER 1979 THROUGH FEBRUARY 1980 ---------- 206

APPENDIX C: DATA PROCESSING DEPARTMENT KEYPUNCH STATISTICS ---------- 211

APPENDIX D: MODEL FORTRAN USER FUNCTIONS ---------- 212

LIST OF REFERENCES ---------- 213

INITIAL DISTRIBUTION LIST ---------- 214

I. INTRODUCTION

There are many advantages associated with the maintenance of a capability to simulate both current and proposed operating procedures in a variety of settings. Models have been developed to assist in the decision making process in such diverse areas as traffic control, war games, and for our specific purposes, requisition processing. Models (simulators) that closely approximate an existing operating system can be used confidently to predict the consequences of procedural changes. Models characterized by variables that have been shown to possess particular distributional qualities may have a quantifiable predictive value; i.e., a numeric level of confidence, or degree of certainty, in the predictions obtained can be calculated. At the very least, any reasonably representative model can be used to assess the relative impact of various procedural changes; each proposed alternative is being subjected to identical model assumptions and the degree to which these assumptions may invalidate simulation output can be estimated across the contemplated alternatives. Most importantly, a realistic simulator permits an informed analysis of procedural changes without incurring the costs that would accrue if the system itself were actually modified.

A simulation, or a computerized representation of a particular situation, may be created in the computer language of the modeler's choosing. FORTRAN, COBOL, or even Basic Assembler

Language could be used, albeit with a great deal of detail and difficulty, as the modeling mechanism. Fortunately, simulation languages featuring more concise coding schemes than standard FORTRAN have been developed to facilitate and enhance the modeler's efforts to obtain meaningful predictive results. SIMSCRIPT and GPSS are two such languages that are highly regarded by those familiar with their capabilities.

A GPSS simulation of the requisition throughput process at NSC San Diego was developed in 1973 as an NPS (Naval Postgraduate School) thesis. This effort, which is specified as reference (b) in this study, was an exceptionally well conceived undertaking that possesses enormous predictive value in the hands of personnel schooled in GPSS. Unfortunately, Naval Supply Center resource constraints and workload levels generally prohibit the luxury of maintaining simulation specialists on their roles. In the absence of such expertise, not only is an on-site capability to expand upon the existing GPSS model missing but, more importantly, the modeling details used in the study can not be comprehended. The actual functions being performed by specific GPSS coding is not readily apparent. Explanatory data is provided either through accompany textual explanations or by the inclusion of comment cards at strategic locations within the GPSS deck. In general, except for accompanying flow charts and/or block diagrams, there is no recognized graphic technique to provide a visual display that corresponds to the GPSS (or SIMSCRIPT) coding in the model.

This project duplicates the 1973 study in the sense that its long range goals include the simulation of requisition throughput at NSC San Diego and the analysis of numerous alternative processing methods. There the similarity ends. Based on the premise that a picture is worth a thousand words, the NSC San Diego requisition processing model is developed in a relatively new simulation language called Q-GERT. Under the additional assumption that NSC San Diego would prefer to acquire and maintain an on-site simulation capability, the development of the model becomes the vehicle for the introduction and explanation of the simulation language itself. Therefore, the basic dual purpose short term objective becomes the description of Q-GERT concepts and modeling techniques in sufficient depth to both familiarize stock point personnel with the language and provide an initial version of a model that accurately portrays requisition processing at NSC San Diego.

An on-site simulator is obviously not a necessity. Intelligent decisions regarding the consequences of proposed procedural changes can often be made without the aid of a simulated impact assessment. Furthermore, if a detailed familiarity with the simulator is considered either nonessential or inadvisable in view of the demands on existing personnel, simulations can be conducted by external sources; e.g., the GPSS model could be updated and used to model alternatives selected by NSC San Diego. There is, however, no guarantee that adequate external resources will be available when needed. Furthermore, there is always a possibility that the alternatives modeled may differ to some

degree from those specified by NSC San Diego. Finally, as explained below, model formulation useing Q-GERT begins by developing structured network symbology from which the translation to the simulation cards is directly accomplished. Therefore, the maintenance of an on-site Q-GERT simulator equates to the existence of a current graphic representation of the requisition processing system. The first step in evaluating any proposed change is to revise the graphics of the affected network segment. Therefore, the revised network symbology has already been completed if the change is subsequently incorporated into the system.

There are both training and data processing costs associated with simulating on-site. Personnel must be trained in the Q-GERT symbology and input card development. This study describes a majority of the network graphics and their purpose. The reference (a) text by A. Alan B. Pritsker, the developer of Q-GERT, provides a field-by-field description of each required card type.

There are basically two approaches that can be taken to acquire a Q-GERT data processing capability. The language may be purchased from Pritsker and Associates and loaded locally on disk or some other peripheral device. There may be significant problems encountered with this approach if the intent is to use existing Burroughs equipment. First, the Q-GERT language is coded in ANSI FORTRAN, which can not be directly compiled by Burroughs equipment. The differences in the Burroughs version of FORTRAN are not major, but some conversion would be needed. Secondly, the core requirement to load the 1,000 node

version of Q-GERT will be large. NPS personnel can provide information on core requirements and run times for the smaller 100 node version. Pritsker and Associates, whose address and telephone number are included in the Distribution List, may be able to address, or even refute, the Burroughs incompatibility problem. They, of course, are the only source for pricing information on the cost of acquiring, and perhaps installing, the 1,000 node version of Q-GERT. It should be noted that the purchase and installation of Q-GERT at a local activity having IBM equipment, if there is such an activity, is a feasible alternative. Programs could be submitted either through card or remote input and the FORTRAN compatibility problem would be avoided.

The second approach for acquiring a Q-GERT capability consists of obtaining remote access to an activity that has already purchased the language. NPS is such an activity and, although only the 100 node version is currently operational, the necessary 1,000 node capability will be established in the near future. NPS can provide the details and costs associated with the remote access approach. It suffices to note that the initial model, or revised versions, would be maintained on NPS disks, accessed through a telephone remote, and activated by means of a standard password procedure.

The main advantage of an on-site simulation capability is the flexibility it provides in the analysis of proposed system changes ranging from the reallocation of existing resources to the addition of completely new functional areas. As Chapters 1

through 10 are reviewed, knowledgeable NSC San Diego will identify numerous additional alternatives that could be evaluated; the very process of tracing transaction flow through the model creates speculation about the impact of doing things differently. The Q-GERT concept of graphically displaying the model contributes to a better understanding of the system being modeled and facilitates the identification of processing alternatives. It is not difficult to imagine the system graphics serving as a training device for Management Analysts and Planning Department personnel.

NSC San Diego is requested to assess the potential of the model developed for on-site use and advise Professor F. R. Richards of NPS, autovon 878-2543, of their findings. If the aforementioned costs, which are quantifiable, are considered prohibitive regardless of the potential benefits, then a recommendation of no further effort in this area is appropriate. A management review of the model development chapters may still be useful; processing procedures must necessarily be described during the detailed discussion of the model and alternatives to some current operating practices have been presented.

If model validation and actual simulation runs are considered paramount for the NSC San Diego decision, funding for a second thesis effort when the 1,000 node model is operational will probably be necessary. If the capability is unequivocably desired, the funding of a second thesis project would still appear to contribute to an orderly implementation process. The student, a Supply Corps officer familiar with both Q-GERT and

stock point operations, would be available for consultation on-site regarding model validity, possible revisions, and the identification of processing alternatives to be tested. With the 1,000 node model and the initial Q-GERT card deck at his disposal at NPS, the student could verify (debug) the model prior to arrival at NSC San Diego.

In grand design, an expanded version of this model could develop into a stock point simulator. The existence of a revision representing each major stock point can realistically be envisioned. However, if the enclosed humble beginning is ever perceived as evolving and expanding to that degree, a few preliminary cautions should be heeded. As detailed as the figures in Chapters 6-10 may appear, this model version may be viewed as sacrificing efficiency for the sake of illustrative symbology. Consequently, some rather cumbersome adaptations of basic Q-GERT concepts were used in place of more efficient programming methods; e.g., the messenger service modeling approach described in Chapter 6. The efficiency can be improved through the development of FORTRAN program segments to replace the more inefficient segments of the model. The use of such program inserts, which serve to provide Q-GERT a practically unlimited modeling capability, was deliberately avoided in this study; FORTRAN insert functions cannot be described using standard Q-GERT symbology and their use obscures the graphic details associated with that segment of transaction processing. Simply stated, the objective was to provide detailed graphics and guidance on Q-GERT, not FORTRAN. Based on the review of this study by Pritsker and

Associates, it may be recommended that any universal acceptance and subsequent development of a stock point simulator concept be accompanied by a switch to a simulation language called SLAM, which can be categorized as a combination of Q-GERT and SIMSCRIPT. Regardless of the approach ultimately taken to improve model efficiency, this simplistic initial version remains a logical starting point.

The model was designed to accommodate expansion when, or if, such an action becomes desirable. Areas where expansion might be considered are mentioned throughout Chapters 6 through 10. Chapters 2 through 4 describe an extremely simplified requisitioning processing system and introduce the Q-GERT concepts and symbology needed to model that system. Additional Q-GERT concepts that will be used in later chapters are also covered in detail.

Chapter 5 contains an extremely detailed discussion of requisition processing at NSC San Diego. Requisition categorization and processing specifics for each category, demand exception workload and processing, POE and autodin demand data, and the scheduling of demand processing runs are among the topics presented.

Chapters 6 through 10 introduce additional Q-GERT concepts as they are used, provide the graphic representation of a particular functional area or process such as autodin arrivals, and give a detailed description of transaction flow through the network segment. Chapters 6 through 9 cover the basic model from requisition arrival and categorization (Chapter 6) to the

movement of material from local delivery or to shipping (Chapter 9). Chapter 10 is devoted entirely to the timing of resource availability (personnel, ADP, messenger, etc.) and the shifting of daily demand patterns.

Chapter 11 delineates modeling techniques that should be closely reviewed during the verification process, suggests alternative requisition processing schemes that could be evaluated in a subsequent thesis effort, if forthcoming, and provides concluding comments that include a sincere statement of gratitude to the many NSC San Diego employees who were most unselfish with both their time and assistance.

It is regrettable that time constraints and the nonavailability of the larger (1,000 node) Q-GERT version combined to preclude either full model or segmented simulation runs. Samples of standard Q-GERT output, which was the only statistical data programmed in the initial version, may be obtained from either NPS or, one would assume, from Pritsker and Associates. Reference (a), Modeling and Analysis Using Q-GERT Networks, contains numerous and excellent examples with accompanying illustrations of standard Q-GERT output. A segmented approach to running the model, which contains over 400 nodes, posed the problem of defining a segment of less than 100 nodes that could be meamingfully interpreted. Since developing such a model involved extraction of segments from all chapters, the ultimate requirement was the development of a completely new model, a process that simply could not be accomplished in the limited time remaining.

II. THE SIMPLIFIED MODEL

Figure 2-1 depicts an extremely simplified version of the requisition processing procedure. It represents the basic functions that must be performed at any stock point to process a customer request and effect the subsequent issue of the required material. Inherent in the procedure illustrated are numerous assumptions that are initially made to facilitate introduction of basic Q-GERT symbology at the least detailed level possible.

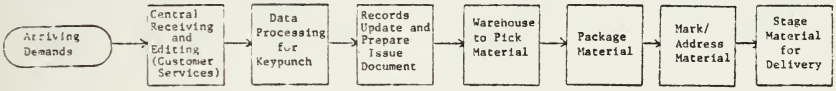


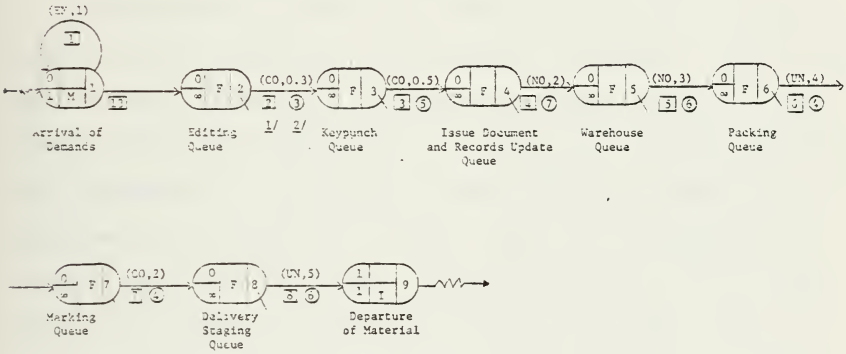
Figure 2-1. Simplified Requisition Processing Model

First, it is hypothesized that each requisition is processed in an identical manner; i.e., there is initially no priority scheme that distinguishes one request from another and each requisition must be processed by all system components.

Secondly, it is initially assumed that each request results in an issue. Gone for the time being are such minor annoyances as editing and keypunch errors, nonavailability of material whether NIS (Not in Stock) or NC (Not Carried), demand processing exceptions, and warehouse refusals. However, these and other

actual processing techniques that are more representative of actual system operation will beintroduced as the Q-GERT model is expanded to incorporate system complexities.

Figure 2-2 represents the Q-GERT symbology corresponding to the basic system described above. This system will be discussed at a level of detail sufficient to serve as the mechanism for the introduction of basic Q-GERT concepts as described in Chapter 2 of reference (a).



1/ Boxes 2 through 3 represent the activity described under the preceding queue.

2/ Circles beside activities 2 through 3 contain the number of servers available to perform the indicated activities.

Figure 2-2. The Q-GERT Simplified Model

Inasmuch as this graphical representation contains a series of slightly dissimilar nodes connected by branches it will henceforth be designated a Q-GERT network. The nodes are identified by the number in the far right partition. Node function

varies by type and each node illustrated is discussed in detail below. Network activities - editing, keypunch, etc., - are performed on the branches of the network and are identified by the number in the box under the branch; e.g., the designation $\boxed{2}$ represents the edit activity of function. Branches generally represent the passage of time, or service time, in the network. When specified, the circled number beside the activity number beneath the branch indicates the number of identical servers available to perform the required activity.

Transactions, in this case requisitions, flow through the network and are serviced on the network branches. Node 1, the source node, functions as a demand generator and will be discussed later. It suffices to note that the arriving transactions/demands are initially processed at the editing station represented by activity 2. Since there are only three ③ servers available to perform the edit function, it is likely that the requisitions will have to await service. Hence the insertion of node 2, a queue node (Q-node), between the source node and the edit activity. In fact, service activities are always preceeded by Q-nodes and, for the time being, only by Q-nodes.

A description of the partitions in queue node 2 is provided in Figure 2-3. Note that the remaining Q-nodes in this simplified network, nodes 3 through 8, are identical except for the node number associated with each. All are initialized with zero transactions/demands awaiting service and there is no limit on the number of transactions that can accumulate at each

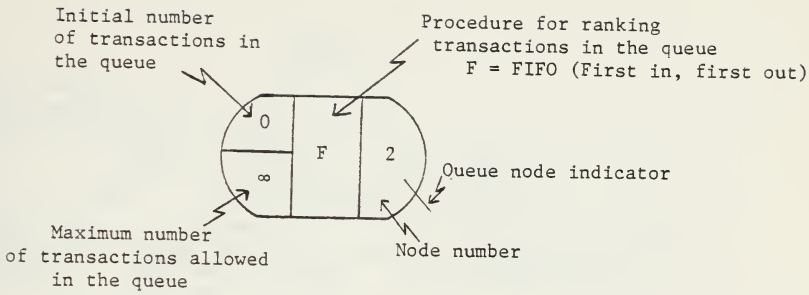


Figure 2-3. The Q-Node

queue. Finally, since the requisitions are indistinguishable by assumption, they are simply processed sequentially, or first-in-first-out as indicated by the F in the center partition. Other ranking possibilities and techniques will be discussed later. However, it should be emphasized at this time that Q-nodes preceed service activities and the ranking of transactions (demands) is accomplished solely to designate which item will be processed by the next available server from the activity immediately following the Q-node.

Figure 2-4 provides a similar overview of the source node, node 1, partitions. Designation of the upper middle partition is deliberately omitted. Alternatives to the M specification in the lower middle portion will be introduced later. Since the node illustrated is a source node, the M designation is basically redundant. Each transaction generated at a source

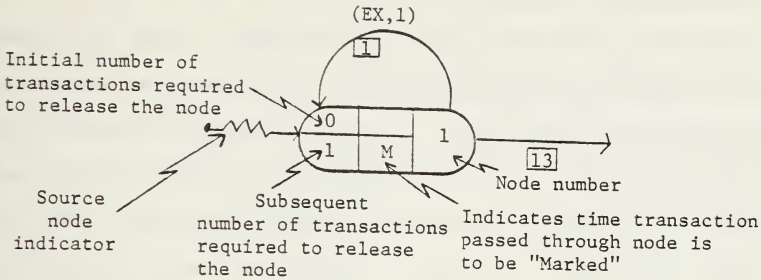


Figure 2-4. The Source Node

node is automatically assigned a mark time representing the transaction time of origin. Unless subsequently altered, this mark time will accompany the transaction through the network and is defined as a transaction attribute. Note that there are two branches emanating from the source node. With only one transaction required to release this node as indicated in the bottom left partition, each nodal release will result in identical transactions being routed along both the branch/activity labeled 13 and the activity labeled 1. This node serves as an example of the deterministic branching process in Q-GERT. The transaction could have been routed along numerous other branches. When deterministic branching is used, the release of a node leads to the routing of an identical transaction on each branch. Note that there are no server designations on either of the branches from the source node. Since this node is not a

Q-node, the activity following it can not be a service activity.

It has been noted that network branches represent the passage of time. The notation (EX,1) above the activity 1 designator represents the specified method for computing the delay between releases of node 1. This delay represents the time between arrival of demands and (EX,1) indicates that the delay will be taken from an exponential distribution with parameters defined in parameter set one. The Q-GERT input cards will contain both an ACT card to describe activity 1 and a PAR card providing the required parameter values for an exponential distribution. Numerous distributions are available to model activity times. Appendix A lists those discussed in reference (a). Note on Figure 2-2 that activities 4 and 5 feature normally distributed service times with parameter set numbers 2 and 3 providing the appropriate distributional information. Activities 6 and 8 exhibit service times from a uniform distribution described in the indicated parameter sets. However, the specification CO for activities 2, 3, and 7 represents a constant function and the number following CO is the number of time units required to perform the activity. Finally, activity 13 between nodes 1 and 2 indicates both that activity numbering need not be sequential and that a branch need not represent the passage of time. The absence of an activity time designation constitutes a (CO,0) distributional assumption or a zero passage of time. Therefore, the requisition arrival time corresponds to

entry into the edit queue in the Q-GERT simplified model depicted in Figure 2-2.

Node 9 in Figure 2-2 need not be labeled here. The I in the bottom middle partition indicates that interval statistics are to be collected; i.e., the difference between the time of arrival at node 9 and the time of origin at node 1. Otherwise each partition is defined exactly like the source node illustrated in Figure 2-4. The initial and each subsequent arrival of a transaction, the material necessary to satisfy a demand, will release node 9 and prompt the collection of interval statistics representing that requisition's time in the system. The inclusion of the symbol $\rightsquigarrow$ on the right side of node 9 serves to designate it as a sink node. If the symbol were omitted and the transaction routed elsewhere, this node would be categorized as a statistics node. A sink node can be viewed as the mechanism by which a completed transaction departs the network. Q-GERT simulation runs are often terminated on the basis of a specified number of sink node releases.

III. DISCUSSION OF THE SIMPLIFIED MODEL

An intuitive appraisal of the Figure 2-2 simplified model leads to the conclusion that it does not represent a particularly challenging problem. Simulation runs would lead to the automatic generation of relevant Q-node and service activity statistics by the Q-GERT Analysis Program. These statistics include average number of transactions in each queue and server utilization data. Therefore, assuming activity and arrival distributional assumptions are correct, the simulations would be most useful for identifying potential backlog problems and excess or inadequate resources at each service activity. If the servers could be used at any activity within the network, the simulation runs could be used to generate the "best" possible allocation of resources within specified constraints. Nevertheless, the simplified model is useful as a basis for the introduction of Q-GERT symbology and as a point of departure for modeling the NSC San Diego requisition processing procedure.

The number of servers assigned to each Figure 2-2 activity and the specified service time distributions are strictly hypothetical and used only for Q-GERT illustrative purposes. As the NSC San Diego model is developed, the service times assigned will generally be identical to those used in reference (b), which were based on the DIMES (Defense Integrated Management Engineering Systems) study specified in reference (c) and conducted in 1968. Departures from the use of these standards, which are of

dubious validity if only due to technical innovations in the last 12 years, will be noted during the model development. It should be emphasized at this point that the usefulness of any Q-GERT model is directly related to the validity of the service time assumptions which, if correctly established, emanate from a series of time and motion studies that provide a representative sample of service times as an input to curve fitting tests. This procedure enables the modeler to express a degree of confidence in his results rather than placing the validity of his model at the mercy of the distributional assumptions. Unfortunately, the latter undesirable situation happens to be the case in this model. Time constraints precluded the development of current standards for each service activity. Fortunately, however, more accurate standards can easily be incorporated into the existing model. The activity card and, if necessary, the accompanying parameter card corresponding to this service activity must be changed to correspond to the new service time distribution annotated on the revised branch.

As a final comment on Figure 2-2, the function performed by activity 4, records update and issue document preparation, is basically a mechanized function performed by the computer CPU (Central Processing Unit) in conjunction with appropriate peripheral equipment. In the simple model this process can be visualized either as a completely manual or partially automated activity. How it is done is basically irrelevant; the important factor is the validity of the assumption regarding how long it takes to perform the function.

This concludes the discussion of the simplified model featuring sequential requisition processing through a series of service activities with all transactions (requisitions/demands) being satisfied. Perhaps such a model would be appropriate for a company such as a discount stereo distributor who begins each day with a zero backlog (initial number of transactions in each queue is zero), receives telephone orders for a specified time period each day, always satisfies each order through various local sources, and closes when all orders have been staged for delivery. As illustrated, however, the Figure 2-2 model wouldn't provide an accurate assessment of the stereo distribution process because it lacks a timing mechanism to terminate the arrival of transactions (orders) while permitting existing orders to be fully processed. Q-GERT timing logic will be introduced in the course of the model development that follows. However, before beginning to develop the NSC San Diego processing procedures, some additional basic Q-GERT concepts must be presented.

IV. ADDITIONAL BASIC Q-GERT CONCEPTS

A. THE REGULAR NODE

Figure 4-1 depicts the most common Q-GERT node, the regular node. In general, the regular node functions to route transactions and assign attributes as discussed later during the model development.

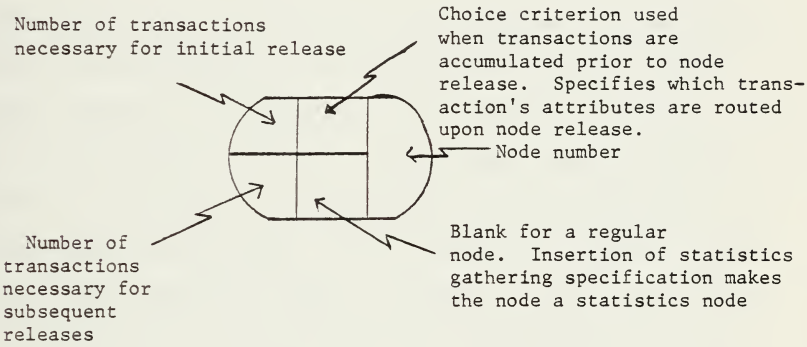


Figure 4-1. The Regular Node

The use of the middle partitions will be discussed below when the accumulation of transactions is addressed. These partitions deal with a decision-making process based on attribute values which will be introduced later. The only attribute encountered thus far is the automatically assigned mark time designator. When not used to assign attributes or accumulate

transactions, the regular node usually appears in the simple form illustrated in Figure 4-2.

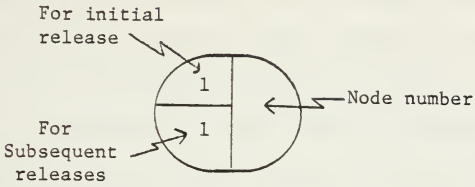


Figure 4-2. The Simple Regular Node

Note that the value 1 for initial and subsequent release indicates that no accumulation of transactions is taking place. Therefore, there is no requirement for a center partition. The converse is not true, however. Values other than 1 could be assigned to the initial and subsequent release partitions with no center partition defined. In that case, the default values for the center partitions shown in Figure 4-1 will be assigned.

The regular node functioning as a transaction accumulator is illustrated in Figure 4-3. It may appear in either of the forms indicated.

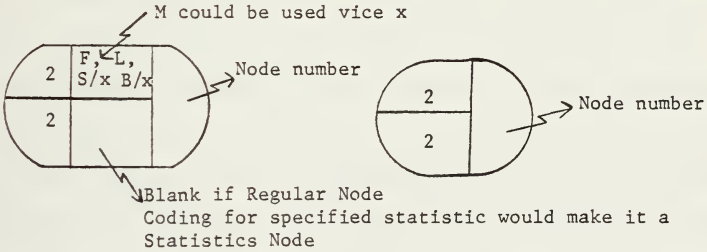


Figure 4-3. Regular Node as a Transaction Accumulator

The partitions are defined on Figures 4-1 and 4-2. The value of 2 for initial and subsequent nodal release is an example only. The possible values for the upper middle partition are shown and represent First, Last, Smallest, and Biggest, respectively. This accumulator function serves to eliminate transactions in the network. The required accumulation of input transactions leads to the release of only one transaction. Therefore, since each transaction possesses at least one attribute, the mark time, and often more than one, it is necessary to designate which transaction's attributes will be routed when the node is released. An F designation specifies "route the first transaction's attributes"; similarly, the L indicates the last transaction's attributes should be routed. However, when B or S is used in the upper segment, the indicated /x symbol should accompany it since x designates the relevant attribute. Therefore, B or S indicates that the attributes of the transaction having the Biggest or Smallest value of attribute x should be routed. For example, the dollar value of a requisition may be assigned as an attribute of that transaction. Then the requisition having the highest dollar value could be selected from an accumulation of demands. Note that an M may be used instead of an integer x. The M represents the mark time of the transaction. In the absence of a center partition, the attributes associated with the last arriving transaction are routed. The accumulation function was introduced to illustrate the diversity of Q-GERT. Since each requisition

must be processed in the NSC San Diego model, accumulation of transactions will not play a direct role in subsequent model development.

B. BALKING AT Q-NODES

Q-nodes will now be revisited to illustrate the concepts of balking and blocking. Figure 4-4 is a labeled Q-node and is similar to the Q-node specified in Figure 2-3.

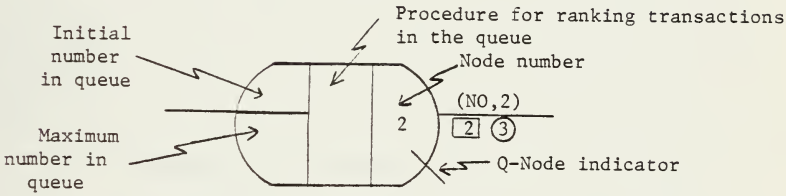


Figure 4-4. The Q-Node Revisited

Recall that a service activity follows a Q-node; in this case, service activity 2 featuring 3 servers is indicated. If an initial number in the queue other than zero is specified, Q-GERT assumes that all servers are busy and schedules service time completions accordingly. Therefore, placing a 2 in the initial number section of Q-node 2 indicates there are 5 transactions in the system; i.e., 2 awaiting service and 3 being serviced by the servers in activity 2.

The queue capacities illustrated thus far have been infinite. Suppose Q-node 2 above has a maximum queue capacity of 6. Further assume that the queue is "full" and a seventh transaction

arrives. This additional transaction can not be accommodated at Q-node 2. Therefore, Q-GERT permits the modeling of transaction balking as illustrated in Figure 4-5 or, if appropriate, blocking of the service activity preceding Q-node 2 (Figure 4-6).

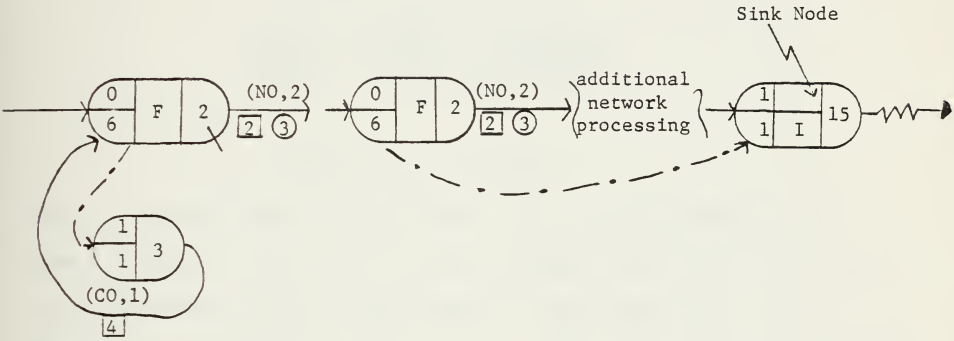


Figure 4-5. Balking

The balking situation illustrated on the left of Figure 4-5 provides for the return of the transaction to the Q-node after one time unit (CO,1) until the transaction is accepted. The dot-dash line represents a balking action which would be described on the Q-GERT card corresponding to Q-node 2. Therefore, there will be no activity card describing the dot-dash branch from Q-node 2 to regular node 3. In fact, nonsolid branches, and others will be encountered, are not considered activities by Q-GERT. The balking scenario depicted on the right side of Figure 4-5 depicts a transaction being balked out of the network while having interval statistics maintained at the sink node.

C. BLOCKING SERVICE ACTIVITIES

Figure 4-6 illustrates the phenomena of blocking that can occur when a service activity output is routed to a Q-node with a finite queue capacity.

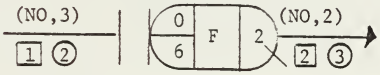


Figure 4-6. Blocking

This situation occurs when Q-node 2 is at its capacity and the servers at activity 1 can not proceed until the transaction just completed can be transferred to the Q-node for activity 2. Specifically, blocking occurs if at least one of the two servers at activity 1 has completed an activity but can not begin to process another transaction from the Q-node (not shown) preceding activity 1 due to the inability of Q-node 2 to accept another transaction. If the blocking function is included in a model, it will be indicated on the Q-GERT card describing Q-node 2.

D. PROBABILISTIC BRANCHING

Thus far all branches leaving the nodes described were deterministic. That is, each release of the node resulted in the transaction(s) released being routed along each branch. Prior to commencing the model formulation, probabilistic branching must be addressed. Figure 4-7 illustrates probabilistic branching from a regular node.

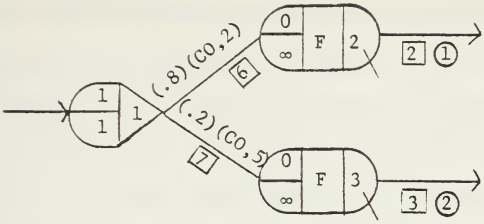


Figure 4-7. Probabilistic Branching

A transaction leaving node 1 will take branch/activity 6 with a probability of 0.8 and will encounter a constant 2 time unit delay while traversing that branch. Conversely, activity 7 with its constant 5 time unit delay will be undertaken with probability 0.2. Therefore, a transaction leaving node 1 will take one branch or the other, but never both as in deterministic branching. The symbol ◺ on the right side of regular node one contains the node number and indicates that probabilistic branching applies. Naturally, the sum of the probabilities on the branches leaving the node must equal 1. Both probabilistic and conditional branching, which will be introduced when used, will often be encountered in the NSC San Diego model.

E. Q-GERT INPUT CARD OVERVIEW

Finally, some additional comment on the cards required to actually conduct an analysis of a Q-GERT network is required. Perhaps the most impressive feature of Q-GERT is that the vast majority of the input cards are created directly from the

graphical representation of the network. In general, there is a card corresponding to each node, each activity, and each parameter set referenced to describe an activity duration. This series of cards plus a GEN card to provide initializing data and simulation termination rules and a FIN card to signal the end of the data describing the network are all that are needed to effect a simulation of basic Q-GERT networks. Although the situation becomes more complex as subnetworks are added, reference (a) provides excellent formats describing the fields of all required input cards. Therefore, a detailed description of input card development will not be included.

V. NSC SAN DIEGO DEMAND PROCESSING DISCUSSION

A. REQUISITION CATEGORIZATION

NSC San Diego customer demand can be divided into the two major categories of autodin and POE (Point of Entry). Autodin requisitions are further subdivided into IPG (Issue Priority Group) I, II, and III requests since response time standards established by reference (d) necessitate different processing methods for each category. POE requisitions are also processed according to IPG. However, further subdivisions within each IPG must be considered if the model is to resemble reality. For example, POE IPG I requisitions can either be "Bearers" (Walk-Throughs) or be unaccompanied such as a message requisition. POE IPG II transactions may be QUICK PIC, unaccompanied, or, to a limited degree, special program requests. Finally, POE IPG III transactions may be subdivided into requests for provisions, special program requirements, SERVMART replenishments, and the largest subcategory designated "OTHER". Each group is processed differently. Table 5-1 provides a brief description of the processing method for each.

MAJOR CATEGORY	IPG SUBDIVISION	SECONDARY SUBDIVISION	PROCESSING OVERVIEW
AUTODIN	I	N/A	Routed to Customer Services by Messenger. Input by remote. Issue document kicks out at Customer Service. Sent to warehouse by messenger. Normal issue operations interrupted to pick material. Gets priority packing on special line. Assigned fastest shipping/delivery method.
	II	N/A	Input to next autodin batch processing run (six each weekday). Issue ducument included in IPG II lot the following morning. In 2nd lot processed each day (after QUICK PIC).
	III	N/A	Same as II above except lotted with other IPG IIIs later on next day's issue and packing schedule.
POINT OF FOCUS	I	BEARER	Hand carried to Customer Services. Entered by remote. Bearer takes issue document to appropriate warehouse. Material picked immediately. Packing not necessary.
		OTHER	Queued in Customer Services upon arrival. Then same as autodin IPG I above when removed from queue for service.
	II	QUICK PIC	Requisitions dropped off at designated area pickup points. Dropped off at Customer Services by NSC driver. Keypunched on day and evening shift. Taken to DPD at end of second shift. Special batch processing run and sort during night. Issued first the next morning. Delivered to designated location for customer pickup by 1400 the next day. Consolidated but not packed.
		SPECIAL PROGRAMS	Discussed under POE IPG III below. IPG II special program requests handled exactly like IPG IIIs up to time issue documents are prioritized (lotted) for issue. Avg 107/day.
		OTHER	Edited in Customer Services and, if keypunched, entered by remote to either put transaction "in process" or refer it. If from mechanized ship (no keypunch needed), forwarded to DPD for batch demand processing at next opportunity. Included in issue lot with autodin IPG II the next day. In process procedure discussed further in text of Chapter.
	III	SERVMART	Mechanized SERVMART system (EPOS). Daily replenishment tape processed each night and issue documents constitute special lot. Picked (Issued) after Group IIs after 24 hour programmed delay. Avg 255 replenishments/day.
		DRY PROVISIONS	Edited in special section of Customer Services. Sent to DPD for keypunch at the rate described in Appendix C. Batch processed after keypunch and issue documents delivered to warehouse next morning (No 24 hour delay).
		SPECIAL PROGRAM	All customer requisitions (IPG II and III) are handled the same. Processed in special section of Customer Services. Keypunched in DPD. Subjected to 3 distinct runs to obtain pricing information prior to actually processing for issue. Time from receipt of requisition until issue/referral extremely variable. Avg IPG III daily input over Appendix B data base was 540/day.
		OTHER (MAJORITY OF IPG III)	If keypunch required, sent to DPD keypunch, batch processed, delayed 24 hours and lotted behind all IPG II and SERVMART issues. If from mechanized source, keypunch is bypassed and batch processing occurs. In either case, processing results in comingling with autodin IPG IIIs.

Table 5-1. Requisition Processing Overview

There is a tertiary subdivision of selected POE categories that is implied in the processing overviews in the table. Namely, if the requisitioner has a mechanized system such as SUADPS (Shipboard Uniform Automated Data Processing System), then the keypunching function need not be performed at the Supply Center. The mechanization distinction must be made for all POE secondary subdivisions except Special Programs, SERVMART, and dry provisions. Although the number of mechanized customers is a function of ship operating schedules and will vary considerably, it is estimated that 25-33% of all POE requisitions submitted to NSC San Diego are in a mechanized format. As a final comment on Table 5-1, it must be emphasized that deviations from the strict categorization portrayed do exist. For example, IPG II CASREPTs can and do quality as Bearer requisitions. Nevertheless, only the categories specified and the mechanization feature will be used to identify requisition types in the model.

B. QUICK PIC AND BEARERS (WALK-THROUGHS)

The data base used for the Appendix B demand calculations was October 1979 through February 1980. This period was chosen to correspond to the advent of the QUICK PIC program. Prior to October 1979, NSC San Diego permitted walk-throughs (Bearers) on both IPG I and II requisitions. Each walk-through represented an interruption to normal processing and a detrimental impact on the response time associated with the issues that were subsequently delayed. Therefore, except in the case of IPG II

CASREPTs, special project codes, and designated types of material such as gas cylinders, walk-throughs were restricted to IPG I requisitions and QUICK PIC was established to provide an expedited response system for IPG IIs that heretofore had been submitted as Bearers. Requisitions left at designated drop points are picked up by an NSC driver, processed and sorted in a special run, picked/issued first on the next working day, and staged at National City for customer pickup at 1400. Therefor, a one working day turnaround time applies. The program appears to be working extremely well. The average daily number of Bearers, and thus the number of routine processing interrupts, have greatly decreased. Table 5-2 shows the Bearer average for each day of the week and the percentage of that day's POE IPG I input that the average represents.

DAY OF WEEK	BEARER AVG	STD DEVIATION OF BEARER AVG	BEARER AVG % OF POE IPG I DAILY AVG FROM APPENDIX B
SAT-MONDAY	134	75.6	66%
TUESDAY	83	20.5	45%
WEDNESDAY	76	27.7	50%
THURSDAY	85	31.5	56%
FRIDAY	98	35.3	54%

Table 5-2. Bearer Statistics

Using column 4 of Table 5-2, the average Bearer percentage of POE IPG Is across the week then computes to 54.2% with a standard deviation of 7.8%.

The reference (e) Customer Service Feeder Reports do not provide a QUICK PIC count although the value has been included in the Hot Line IPG II daily total. However, available reports do indicate a QUICK PIC average issue quantity of 110 per day. Since it can only be assumed that QUICK PIC faces the same probability of availability as other IPG II requisitions, the average daily number of QUICK PIC requisitions is projected at 162 per day based on a 68% gross availability rate.

C. DEMAND PROCESSING PROCEDURES

As used in this study, demand processing refers to the function of checking an item's on-hand asset position and taking one of the following three actions:

. Committing available assets to satisfy a requisition

. Placing a requisition "in-process" based upon the current availability of assets with no commitment/reduction of on-hand assets at that time

. Referring the transaction based on nonavailability of assets. Special advice codes such as "Fill or Kill" that serve to eliminate the referral will be ignored for the purposes of this report.

The demand processing procedure is performed by two UADPS-SP (Uniform Automated Data Processing System - Stock Point) programs. Both versions will refer transactions at the time of processing based on nonavailability of assets. The on-line version is activated by transaction/requisition input from remote terminals and may be used to either commit assets and

receive a corresponding issue document for immediate processing or place transactions in-process. The second program is used to perform batch demand processing. It is run periodically throughout the day and results in either a commitment of assets or a referral (partial issues are ignored) for each requisition processed. The batch processing mode, as currently used, can be viewed as a procedure for placing issue document images on tape for further processing if assets were available.

All IPG I requisitions, both autodin and POE, are input via remote terminals and either processed to completion or referred. Autodin IPG II and III requisitions are received on tape six times a day and batch processed each time. The first batch run is scheduled for 0330 and the last at 2200. Therefore, autodin IPG II and III processing can be viewed as both a generator of referrals based on the gross availability at the time of batch processing and an originator of six tapes containing issue document images that will undergo additional processing.

There are three additional batch processing runs daily. QUICK PIC requisitions are batched separately at 0100 and all Provisions requests are processed at 1800 daily. These categories are neither delayed by the Production Planning routine nor subjected to the standard lotting process; they are simply sorted by location and issued the next working day. The final batch run serves as a supplement to the six autodin runs already mentioned. It must be noted that while the autodin runs are scheduled to accommodate the IPG II and III autodin input, any available POE input will also be batch processed during the six

runs. Therefore, all POE input except Provisions and QUICK PIC will be processed during one of the seven aforementioned batch runs. Of course, nonmechanized input can not be batch processed until it has been keypunched as described in Chapter 7.

The astute reader will recognize that all the Table 5-1 categories have now been addressed except for the POE IPG II requests from nonmechanized customers. This category of transaction is put in-process from remote terminals during the course of the day and no assets are reserved/committed for these demands until approximately 1800 when the UADPS-SP program that releases in-process issues generates another tape containing issue document images. To illustrate the consequences of this procedure, it must be noted that batch processing, which commits assets, may allocate material to a lower priority requisition if the batch run is conducted <u>after</u> the POE IPG II is put in-process <u>but</u> <u>before</u> its 1800 release. Secondly, POE IPG IIs put in-process after 1800 by the Customer Service second shift are necessarily delayed approximately 24 hours and subjected to another series of batch runs that may commit available assets. This factor becomes particularly relevant when it is realized that placing POE IPG II requisitions in-process is of secondary importance with respect to processing autodin and POE IPG I transactions. Therefore, it may reasonably be assumed that many of these in-process actions are initiated on the second shift and, at least potentially, accomplished after 1800. In recognition

of these possible adverse consequences, a rescheduling of the in-process release program to a later time (nearer to 2400) is being considered. In addition, discussions currently being held will probably lead to revised demand processing batch procedures that will function to place some, and possibly all, IPG III demands in-process where, when released, they will be issued after IPG IIs.

The information provided thus far in this chapter has been presented to emphasize the complexity of requisition processing procedures and provide the rationale for numerous features that will be incorporated into the model. Prior to proceeding with a discussion of the NSC demand data contained in Appendix B, it is imperative to realize that the various tapes containing issue document images are all run through appropriate local Production Planning/sorting/lotting programs beginning at approximately 0300. The relevance of this factor is that the issue documents associated with transactions that were either batch processed or released from in-process are not delivered to the appropriate warehouse until, at the earliest, 0730 the next working day.

D. NSC SAN DIEGO DEMAND DATA ANALYSIS

Appendix B contains daily requisition frequency averages for the five month period encompassing October 1979 through February 1980. As previously mentioned, the beginning of this period corresponds to the commencement of the QUICK PIC program. Daily averages were computed from the reference (e)

reports and include IPG I, II, and III averages within both the autodin and POE categories. Provisions requisitions are listed as a separate POE category and are considered IPG III requests despite the existence of occasional IPG II demands.

The data was displayed in the Appendix B format to determine whether similar IPG percentages applied to autodin and POE requests. The data illustrates that the IPG I percentage ranged from 14.5% to 21.2% for autodin transactions and from 4.7% to 6.5% for POE demands. This significant difference effectively ruled out any assumption that IPG percentages were consistent for both major transaction categories. That factor and, perhaps more importantly, the extended portion of the day for which autodin arrivals occur led to the decision to model the arrivals separately. Therefore, Chapter 6 describes distinct arrival and transaction categorization processes for each type.

A cursory review of Appendix B indicates an excessive amount of variability in the category averages. In fact, had the replacements indicated in the appendix footnotes not been made, the applicable standard deviations would have been even higher. In view of the nature of the data, the time between arrivals will be assumed to be uniformly distributed for both autodin and POE source networks. Some consideration was given to defining gamma distribution parameters that would more accurately reflect the interarrival times implied by the Appendix B demand data. However, the lack of any definitive information relating input levels to time of day made this approach significantly less attractive. If a more detailed analysis of the requisition

arrival process is conducted in the future, the model may easily be modified through the replacement of the existing ACT (activity) and PAR (parameter) input cards described in Chapter 6.

Since a uniform time between arrivals implies that each duration within a specified interval is equally likely, the maximum and minimum durations are the only values specified by Appendix A as necessary to define a UN (uniform) parameter set. Using Thursday demand data from Appendix B and assuming arrivals may occur over a 24 hour period, the uniform distribution parameter set (max and min) will be computed for <u>autodin</u> arrivals in the following manner:

. An IPG percentage weighted standard deviation will be computed using the formula

$$\sum_{i=1}^{3} \frac{\%\text{ of IPG } i}{100} \times \text{S. Deviation IPG } i.$$

The computation for Thursday is given by

$$(.168 \times 120.62) + (.428 \times 445.37) + (.404 \times 243.27) \cong 309 .$$

This calculation can be considered to represent an expected standard deviation across all IPGs.

. The maximum and minimum time between arrivals will then be calculated as the times associated with the arrival of a requisition quantity two weighted standard deviations lower and higher than the daily average. The maximum time between arrivals would occur when the number of arrivals was two weighted standard deviations below the average; i.e., 1829 - 618 = 1211

arrivals which implies a 0.0198 hour (24 ÷ 1211) maximum. The minimum is given by 24 ÷ (1829 + 618) = 0.0098.

The parameter set describing the POE arrivals may be defined in a similar, but slightly more complex, manner. An expected standard deviation across all Hot Line IPGs would be computed as

$$(.06 \times 76.47) + (.615 \times 763.77) + (.325 \times 339.9) \cong 585$$

for Thursday's data. Adding two standard deviations (1,170) to the Hot Line daily average of 2,551 yields 3,721 as the number of requisitions corresponding to the minimum value of the uniform interval describing Hot Line arrivals. Likewise, subtracting 1,170 indicates that 1,381 demands define the maximum interval point. However, a Hot Line interval does not account for all POE input; Special Program, provisions, and SERVMART requests are not included for the following reasons:

. The reference (e) reports generally allotted the same number of demands for provisions to each day of a given week/reporting period. This occurred because weekly, vice daily, provisions counts were provided.

. Special Program demand submission patterns were necessarily very sporadic due primarily to the accumulation of requests for specific programs. The existence of numerous "zero transaction" days and widely fluctuating quantities made it prudent to simply compute a daily average of 107 IPG II requests and 590 IPG III.

. The only SERVMART replenishment count data that was readily available was a 255/day average.

To account for these three special categories, which will immediately be extracted and separately identified in the model, the minimum and maximum POE endpoints described above must be shifted. Therefore, the sum of the daily averages for Special Program, SERVMART, and provisions (specified by day) requests must be added to both sides of the interval. Thursday's uniform demand interval will then be defined in the following manner: [1,381 + (107 + 590 + 255 + 550), 3721 + (107 + 590 + 255 + 550)] or [2,883, 5,223]. Finally, the time between arrivals associated with the appropriate requisition quantity is calculated by dividing each value into 8 hours, the time period over which POE arrivals will occur. The resulting interval is [0.0015, 0.0028].

E. EXCEPTIONS AND WAREHOUSE REFUSALS

Numerous unprogrammed interruptions to the demand processing procedure may occur. Demand exceptions and warehouse refusals are two such delays that, when they occur, inhibit further processing until manual corrective action has been taken. In the NSC San Diego model, the necessary corrective action will be taken by the exception processing unit within the Customer Service Division.

A demand exception occurs when a requisition fails one of the many validity checks made by the demand processing program. If the requisition is entered from a remote terminal, the exception, if encountered, will kick out at the remote terminal and be processed immediately. Using terminology that defines the

modeling approach, an exception resulting from a remote transaction input will go to the head of the exception processing unit queue. Exception output from the batch processing runs will be routed to the exception queue and processed in IPG sequence. QUICK PIC exceptions will be processed together at the beginning of each work day. The only data available for computing an exception rate was the reference (e) count of exceptions received during the five month data base. There were 49,655 exceptions lodged against the 644,013 requisitions processed over the same period.

Warehouse refusals occur when insufficient assets exist in the warehouse to issue the quantity specified on the issue document. This situation represents a mismatch in the recorded and actual on-hand quantity and indicates a reconciliation is required. In actual operations a warehouse refusal and partial issue will often occur together; i.e., some assets were on-hand and used to partially satisfy the customer request but the remainder represents a warehouse refusal because the MSIR (Master Stock Item Record) indicated the entire quantity was available. However, the model will not recognize partial issues. The occurrence of a warehouse refusal will indicate that the entire quantity was NIS (Not-In-Stock). Therefore, transactions exiting the processing stream as warehouse refusals will be routed to the exception desk/queue, processed, and removed from the system. Actual subsequent processing would normally lead to a referral based on nonavailability of assets. A 1% warehouse

refusal rate based on a recent NSC San Diego Quality Control study will be used.

It is assumed that the exception total of 49,655 given above includes warehouse refusals that must be subtracted before a demand exception rate can be estimated. Since warehouse refusal rates refer to a percentage of issues rather than requisitions, the 1% rate will have to be applied to the number of issues projected from a 644,013 transaction input. Assuming a gross availability rate of 65%, the number of warehouse refusals over the five month data base is estimated to be 4,186 ($0.01 \times 0.65 \times 644{,}013$). The exception total must be further reduced by an estimated 250 per week input of nonstandard material exceptions that will not apply in this model. Therefore, an additional 5,500 (250×22) exceptions will be excluded from the exception total and it will be assumed that the <u>demand</u> exception total over the five month period was 39,969 (49,655 - (4,186 + 5,500)). The resulting estimated demand exception rate of 6.2% (39,969 $\div$ 644,013) will be used in the model.

SERVMART replenishment requisitions are generated locally using the automated EPOS system. Therefore, under the assumption that demand exceptions seldom occur when using this automated procedure, SERVMART demands will not be tested for demand exceptions. Similarly, provisions requests are arbitrarily excluded from exception testing in recognition of the limited number of fields that must be entered on the prepunched requisitions by the customer and keypunched in DPD.

An appropriate analysis of the demand exception rate would require, at the very least, exhaustive research of the UADPS-SP Program Processing statistics exception data and represents an effort that is beyond the scope of this project. Therefore, the relatively simple computation presented will have to suffice until a more accurate assessment can be made. Although a more recent gross availability rate of 68% is used later in the model, it was not considered necessary to change the demand exception computation, which was based on the lower (65%) availability value. Regardless of the value used, 65% or 68%, an exception rate of approximately 6% is intuitively too high but, if nevertheless accurate, certainly worthy of management attention.

F. MODELING CONSIDERATIONS

Prior to beginning the actual modeling of the requisition processing components, a brief discussion of the modeling approach is advisable. The three principle factors influencing the modeling approach are the desire to gradually and systematically incorporate complexity, the difficulties associated with modeling the timing of requisition processing, and the existence of a maximum node constraint of 100.

Despite possessing many features that simplify the modeling process, Q-GERT appears to lack a programmed approach for accumulating then releasing <u>all</u> transactions after a specified time period. Modeling activities like messenger services, the accumulation of requisitions prior to a scheduled batch run,

and the filling of accumulator lines before releasing material to packing all depend on this principle and are necessary to approximate reality in the model. Therefore, the modeling of such events will have to be accomplished with FORTRAN program inserts. The expanded modeling capability that can be realized through the use of these inserts is one of the most impressive features of Q-GERT. Existing Q-GERT subprograms can be accessed by the user defined FORTRAN segment. Chapter 7 of reference (a) describes the use of program inserts and illustrates the great degree of flexibility afforded the modeler by this feature. However, since a stated objective of this project is to introduce and/or use the maximum number of pre-defined Q-GERT concepts, the use of program inserts will be limited to situations that can not be modeled otherwise.

The timing of the model refers not only to the scheduling of messengers and batch processing runs, but also the switching of shifts, days, and weeks. Since the demand pattern changes from day to day, the arrival rate will differ each day. Therefore, a switching network will be developed to periodically replace the transaction source network. However, the IPG I through III percentages for autodin and POE will <u>not</u> be changed on a daily basis. Six simple weekly averages taken from Appendix B will be used to define the IPG percentages. This step will minimize the number of network modifications that must be made when the day of the week changes without appreciably degrading the model validity. Due to the complexity of timing the model,

a chapter will be devoted to the subject and presented after the model has been completed in a "free-flow" form.

The 100 node limitation and existing time constraints present insurmountable obstacles to both model validation and the generation of representative simulation output. Validation on a piecewise basis could conceivably be accomplished but, as emphasized in the Introduction, there is a time constraint associated with the completion of this segment of an unavoidable two-phased study. Given this time limitation, the validation of the model, whether conducted in a piecewise fashion or through the analysis of initial full model runs, will have to be undertaken during the second phase. Network segments requiring extensive analysis during the validation process are emphasized throughout the remaining chapters and reiterated in the Chapter 11 summary. Since the Q-GERT cards corresponding to the model developed in Chapters 6 through 10 were created, an attempt was made to identify a convenient network segment containing less than 100 nodes that could be run independently. Due to the complex relationship between the Chapter 11 disjoint timing network and the remaining operationally dependent segments, a representative independent model could not be readily identified. Nevertheless, numerous examples of the standard Q-GERT output that would be generated by simulations on a model segment are illustrated in conjunction with the sample problems presented in reference (a).

VI. MODELING THE ARRIVAL AND CATEGORIZATION OF REQUISITIONS

A. ATTRIBUTE ASSIGNMENT

Requisitions arrive at the Supply Center as a readily recognizable member of one of the categories discussed in Chapter 5. Therefore, the arrival process in the model will include not only the generation of demands, but also the designation of a transaction to a category through the attribute assignment feature of Q-GERT. Figure 6-1 shows the symbology necessary to indicate the assignment of a single attribute at a node.

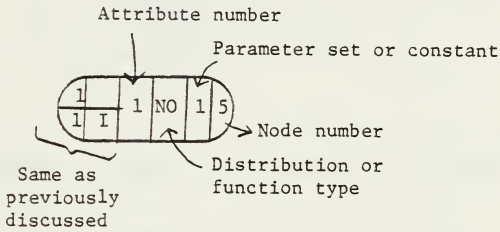


Figure 6-1. Statistics Node Used for Attribute Assignment

Attribute assignment information is always placed in the three partitions directly to the left of the node number. The attribute number affected is at the far left and the method of assigning a value to the indicated attribute is displayed in the remaining two partitions. Figure 6-1 illustrates the case where a value from a normal distribution described by parameter set 1 is being assigned to attribute 1 of each transaction passing through the node. Although a statistics node is used in the

example, attribute(s) may be assigned at any node type that has been presented. However, at each node where an attribute assignment occurs, a VAS (Value ASsignment) card must be prepared in accordance with reference (a) instructions. Any of the distribution types listed in Appendix A except AT may be used to define an attribute assignment.

Figure 6-2 is provided to illustrate the procedure to multiple attribute assignment and introduce an additional attribute assignment technique not given in Appendix A.

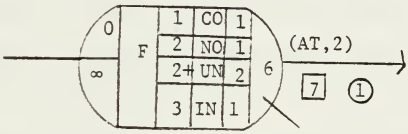


Figure 6-2. Multiple Attribute Assignment at a Q-Node

Attribute 1 is assigned a constant value of 1. Attribute 2 is <u>first</u> being assigned a value from a normal distribution described in parameter set 1 and is then being changed through the addition of a value taken from the uniform distribution described in parameter set 2. Since the time to perform activity 7 is defined as the value of attribute 2, the service time associated with transactions taken from Q-node 6 is the sum of samples from a uniform and normal distribution. If the initial attribute 2 value assignment had occurred earlier in the network, only the 2+ row would have been required to change the value.

The bottom value assignment to attribute 3 is the incremental function. It indicates that attribute 3 of the transactions leaving the Q-node should be sequentially numbered with the first transaction being numbered 1. It is not necessary to start with 1. Any negative or positive number is an acceptable starting point; each successive transaction will be assigned an attribute 3 value that is one unit more positive than the value assigned to the previous transaction.

The model will primarily use attribute assignments of the CO variety. Attributes 1-3 will be assigned constant values to represent the following requisition characteristics:

. Attribute 1 is the IPG indicator with possible values of 1, 2, and 3 representing IPG I, II, and III, respectively.

. Attribute 2 is the keypunch service time taken from Appendix C. It will be assigned one of the following values:

.. 0 mechanized input

.. 0.0032 for provisions transactions

.. 0.0067 for Special Programs requisitions

.. 0.0071 for all other nonmechanized transactions

Although constant keypunch service times are used in the model, Appendix C provides sufficient provisions and DD 1348 data to compute a relatively good estimate of keypunch variability.

. Attribute 3 will be used to establish ranking and processing priorities in the model and may be assigned any of the following values:

.. 0 - Warehouse Refusal

.. 1 - Bearer Requisition

.. 2 - IPG I (autodin or POE)

.. 3 - QUICK PIC

.. 4 - IPG II (autodin or Table 5-1 Other Category)

.. 5 - IPG III (autodin or Table 5-1 Other Category)

.. 6 - Not used (originally reserved for Special Program requisitions, but not needed)

.. 7 - Provisions

.. 8 - SERVMART replenishments

B. CONDITIONAL BRANCHING

The only branching techniques discussed thus far have been deterministic and probabilistic. In order to describe the routing of transactions based on attribute value, two additional forms of branching designated conditional-take-all and conditional-take-first must be introduced. Figure 6-3A illustrates the former type and 6-3B the latter.

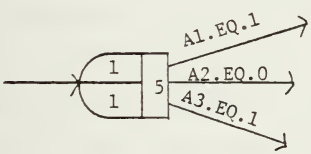


Figure 6-3A. Conditional-Take-All Branching

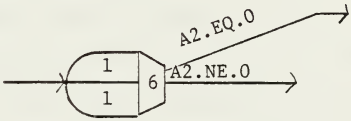


Figure 6-3B. Conditional-Take-First-Branching

Each transaction routed through node 5 above will be forwarded along <u>every</u> exiting branch for which the specified condition is met. For example, using the model attribute assignments previously

presented, a Bearer mechanized requisition arriving at node 5 would lead to a duplicate of that transaction being routed along all three branches. On the other hand, the arrival of a POE IPG III nonmechanized transaction would lead to an error message since none of the conditions would be met; each incoming transaction must satisfy at least one of the specified conditions for both forms of conditional branching illustrated above. The conditional-take-all method will not be used often in the model. However, it is presented to illustrate its potential value to the modeler.

The conditional-take-first branching shown in Figure 6-3B will play a major role in the requisition processing model. In this form of branching, the order in which the conditions are to be evaluated will be specified and the transaction will be routed along the first branch for which the condition is satisfied; no further conditions will be evaluated. Recall that attribute 2 was the keypunch service time and was set to either 0 (mechanized) or the appropriate service time. After ensuring that attribute 2 is set for every transaction arriving at node 6 above, the simple branching illustrated can be used to route transactions to either keypunch ($A2 \neq 0$) or DPD if already keypunched ($A2 = 0$).

Conditional branching can be used at all nodes discussed except Q-nodes where only probabilistic or deterministic branching is permissable. Finally, branching based on specific attribute values is only one of many conditions that can be used for the routing decision. Branching can be based on numerous

other factors such as current simulation time, the relationship of one attribute value to another, and the status (released or not) of a specified node. These conditions are listed on page 146 of reference (a).

C. THE AUTODIN ARRIVAL AND CATEGORIZATION PROCESS

It was noted in Chapter 5 that the autodin arrival process was significantly different from its POE counterpart with regard to both the time over which arrivals occur and the IPG categorization percentages. Therefore, it was concluded that separate arrivals must be modeled for autodin and POE with both displaying a uniform time between arrivals due to large variations in the demand data. Figure 6-4 is the Q-GERT representation of the autodin arrival and requisition categorization process for <u>one day's demand</u> at NSC San Diego. Note that node 1 is not a source node although it is being used to generate and mark transactions in a manner similar to the Figure 2-4 source node. When preparing a Q-GERT input card, node 1 would be designated a regular node with a mark time being assigned. The absence of the —⋀→ indicator on the input side and the requirement for 1 transaction to provide the initial release indicate the source node preceeds node 1 in the network. In fact, the source node will be part of the timing network referenced in the rectangle preceding node 1. This network, which will not only time the daily input but will also shift the day of the week, will be covered in a later chapter. Prior to introduction of the timing network, the transaction flow in the model is constrained only by the delays indicated on the branches and time

spent at Q-nodes awaiting either service or a timing pulse. If no delay is indicated on a branch, the default value of (CO,0) applies. Note that the transaction from the timing network to node 1 is assigned a delay from the same interarrival distribution as activity [1] ; this timing pulse, which activates node 1 for the specified 24 hour period, also represents the first requisition arrival of the day since it is routed along both branches (deterministic branching) leaving node 1.

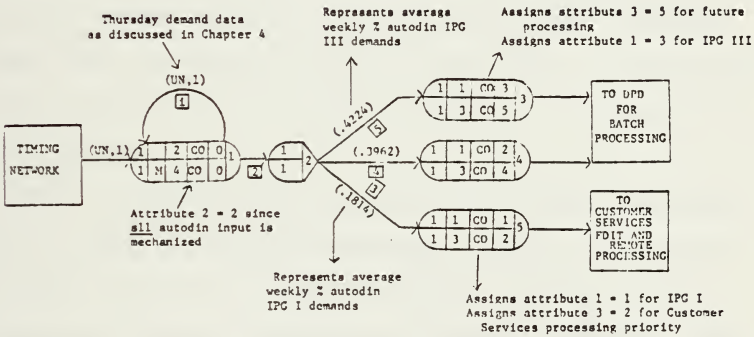


Figure 6-4. Autodin Arrival and Categorization Process

Figure 6-4 illustrates the simplicity of the autodin arrival and categorization process. Since the requisitions are all mechanized, an attribute 2 keypunch service time of zero is immediately assigned to each demand generated. The attribute 4 = 0 assignment will be discussed later. Node 2 provides probabilisitc branching proportional to the simple weekly

average IPG percentages. At nodes 3, 4, and 5 each transaction is assigned an attribute 1 value equal to its IPG. In addition, attribute 3 values of 2, 4, and 5 are assigned to IPGs I, II, and III, respectively, to establish future processing priorities. Modeling nodes 3, 4, and 5 as regular nodes is only appropriate for describing the immediate release of incoming transactions to DPD or Customer Services. In actuality, arriving transactions must await the appearance of a scheduled messenger. Therefore, Figure 6-5 represents a more realistic model of autodin processing procedures and also permits the introduction of two additional Q-GERT concepts, the match node and user functions. The Figure 6-4 value assignment of attribute 4 = 0 at node 1 was made to facilitate the matching process.

Chapter 5 mentioned the absence of a well defined Q-GERT concept to model a scheduled messenger service. The match nodes used in Figure 6-5, nodes 7 and 10, and the network associated with them illustrate one possible messenger modeling scheme.

The match node functions to delay the removal of a transaction from a Q-node until a transaction with a matching selected attribute value arrives at another Q-node. Q-node 5, which was shown as a regular node on Figure 6-4, contains IPG I autodin requisitions with an attribute 4 = 0 assignment from node 1. These transactions are to be forwarded to Customer services for processing. However, match node 7 functions to delay the routing until a transaction with attribute 4 = 0 arrives at Q-node 8.

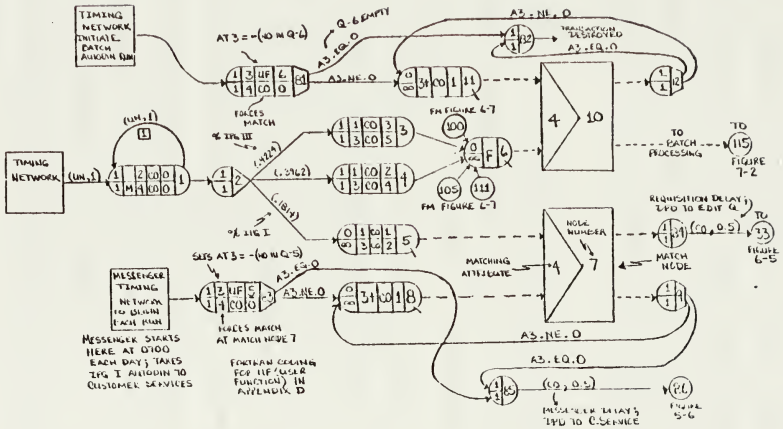


Figure 6-5. Revised Autodin Arrival and Categorization Process

When a match does occur, one transaction will depart each Q-node and be forwarded to nodes specified on the Q-GERT card describing the match node. The nodes on the output side of the match node may be any type previously discussed. Only Q-nodes, as many as five, may comprise the input side of a match node. The dashed lines on both sides of the node indicate that they are not activities and no ACT cards are required; Q-node cards will reference the match nodes and the match node card specifies the Q-node/node routing that will occur upon matching.

It would be permissible to release transactions from Q-node 5 one at a time based upon triggers sent to match node 7 from a Q-node in the timing network. Of course, the arriving matching transaction must have an attribute 4 = 0 and be routed to node 9 by the match node. In that case, the timing pulses would simply depart the network at node 9 with no further routing and one requisition in Q-node 5 would be routed each time. However, the situation that must be modeled is a messenger service with a scheduled departure of all transactions in Q-node 5. Therefore, upon receiving a transaction having attribute 4 = 0 from the timing network, the nodes 83, 8, 7, 9, and 85 logic will effect the desired instantaneous transfer of all requisitions in Q-node 5.

The messenger modeled by the match node 7 network is assigned to Customer Services. His route includes numerous stops that will not be considered in the model. His arrival at DPD in Figure 6-5, the Broadway warehouse, and two Customer Services

queues will be simulated. Four complete rounds will be made during an eight hour working day beginning at 0700. The modeled route is not identical to the sequence of stops actually made. However, the requisition flow and subsequent delays that are initiated upon his arrival are realistic. Each complete round will be initiated by a timing network pulse arriving at node 83 on Figure 6-5. The completion of one round could be used to initiate the beginning of thenext by using a timed modification of mode 83 to inhibit messenger activity after the working day is over. However, the required nodal modification, a concept that will be introduced in Chapter 7, would represent an unacceptable, and avoidable, level of complexity at this stage of model development.

The transaction arriving at node 83 to initiate a messenger run is immediately assigned the indicated attribute 3 and 4 values. Attribute 4 is assigned a constant zero value to force a match at node 7 <u>if</u> Q-node 5 has autodin IPG I requisitions for the messenger to take to Customer Services. The attribute 3 value assignment made by UF (User Function) 5, a FORTRAN program insert shown in Appendix D, will be the negative of the number of requisitions in Q-node 5. If Q-node 5 is empty, attribute 3 (AT 3) will be equal to zero, the upper conditional-take-first branch will be taken, and the transaction representing the messenger will bypass the matching process and be routed directly to node 85. The delay shown on the branch leaving node 85 represents messenger travel time to Customer Services where node 86 is located. Therefore, no attempt will

be made to route autodin IPG I requisitions from Q-node 5 to regular node 84 (via match node 7) when there are no transactions to process.

If Q-node 5 does contain requisitions, attribute 3 of the transaction leaving node 83 will be a negative number with an absolute value equal to the number of autodin IPG Is waiting to be routed. The "messenger" will then be sent to Q-node 8 where his attribute 4 value will be compared to the attribute 4 value of the first requisition in Q-node 5. Since they are both zero, a match will occur and a transaction will depart each Q-node. The requisition leaving Q-node 5 will be routed to node 84 and then delayed 0.5 hours before reaching the edit queue (Q-node 33) in Customer Services. Upon leaving Q-node 8 the messenger transaction will have its attribute 3 value increased by a constant 1 and routed to node 9 via the match node. It is important to note that the match occurred <u>before</u> the value assignment that changed attribute 3 was made; attribute assignments occur after a node is released, but before conditional branching criteria are evaluated. Therefore, the messenger could not have been assigned an attribute 4 value of zero <u>at Q-node 8</u> and ensure an attribute 4 match with Q-node 5; the attribute 4 value assignment of zero needed for the match could not be made until Q-node 8 was released and, paradoxically, a release of node 8 could not occur until the match on attribute 4 was made. Therefore, the match was ensured at node 83 prior to the transaction's arrival at Q-node 8.

When the conditional branching at node 9 is encountered for the first time, the absolute value of the messenger attribute 3 assignment is one less than the original number of transactions in Q-node 5. However, since one requisition departed Q-node 5 at the initial match, the attribute 3 value of the messenger represents the number of requisitions remaining in Q-node 5 at the time of the branching from node 9. Therefore, when Q-node 5 is empty, the messenger attribute 3 value will be zero at node 9 and the branch to node 85 will be taken. If additional autodin IPG Is remain in Q-node 5, the messenger attribute 3 value will represent that quantity and the lower node 9 branch will be taken. The routing back to Q-node 8 has no delay associated with it and the arriving transaction has AT 4 = 0. Therefore, another match occurs, one more autodin IPG I departs Q-node 5, and the messenger transaction's AT 3 value is decremented (in absolute value) by one unit before the node 9 branching conditions are evaluated. The lower branch from node 9 will be taken until Q-node 5 is empty. No simulation time is consumed by the repeated branchings back to Q-node 8 and, in effect, the autodin IPG Is are all removed (forwarded to Customer Services via node 84) at the same time.

The messenger process was presented in detail to minimize the explanation needed for similar transfer networks appearing throughout the model. The Figure 6-5 network consisting of nodes 81, 82, 6, 10, 11, and 12 is logically equivalent and functions to route all autodin and POE transactions in Q-node 6 to a scheduled DPD batch processing run initiated by the

arrival of a transaction at node 81. The batch processing procedure is addressed in Chapter 8. Note that the transaction leaving node 82 is lost to the system vice routed in a manner similar to the messenger leaving node 85. This approach is permissable and node 82 must be included to permit the branching evaluation at nodes 81 and 12 prior to destroying the transaction; i.e., the upper branches of nodes 81 and 12 could not have been used to destroy the transaction through omitting a node to receive the transaction. The branch description provided in the ACT (activity) input card specifies the branching condition to be evaluated and an ACT card <u>must</u> contain a start and end node. On the other hand, the transaction leaving node 85 is routed to node 86 instead of being lost to the system. Consequently, node 85 is not actually needed. The upper branches from nodes 83 and 9 could have been assigned identical messenger delays and routed directly to node 86.

Three additional points must be made regarding Figure 6-5. First, Q-node 6 was added to the Figure 6-4 network to queue IPG II and III autodin and POE demands for batch processing. This was done not only to comply with the requirement that only Q-nodes may serve as match node input, but also to model transaction waiting times; regular nodes such as nodes 3 and 4 can not lead to a delay unless transactions are being accumulated as described in Chapter 4. Secondly, although a match node may have multiple Q-nodes on its input side, one match node could not be used to empty Q-nodes 5 <u>and</u> 6; the circuitry associated with each Q-node represents a different "messenger

system" with a different schedule and, more importantly, the required matching transaction from every input Q-node would cease to exist when the Q-node having the least initial number of requisitions was empty. Finally, all the Q-nodes on Figure 6-5 rank transactions on a FIFO basis. Q-node 6 indicates this fact. The other Q-nodes are assigned no ranking designator to indicate that the default procedure, which is also FIFO, is being used.

It should be apparent that match nodes can be best used to model situations like programmed delays prior to routing of individual transactions and awaiting the arrival of several (up to five) dissimilar components before commencing an assembly operation. The Figure 6-5 messenger application is cumbersome at best. It represents a considerable investment in nodes to provide the additional network logic to effect the transfer and model messenger travel time. Since the dashed lines to and from a match node do not represent activities, they can not be modeled as a delay. However, the only available alternaitve is a variable resource allocation technique that does not represent a significant savings in the number of nodes consumed. Resources will be introduced in Chapter 7 and the use of a variable resource scheme to model a timed release of numerous transactions will be introduced in Chapter 8.

Finally, note that there are no post-arrival delays assigned to the requisitions during the categorization process leading to arrival in Q-nodes 5 and 6. Demand categories are recognizable upon arrival and therefore require no categorization time.

In addition, the sequential activity numbers assigned to each branch on Figure 6-4 are omitted on 6-5. Branches that do not contain activities of interest such as interarrival distributions and service functions referenced on output will not be assigned a specific number and descriptive label. Therefore, only the interarrival branch on node 1 is numbered. The remaining branches will be automatically numbered by the Q-GERT Analysis Program.

Figure 6-5 represents events occurring in DPD. Autodin tape input is actually received in the communications center and routed to DPD by messenger for segregation of IPG Is and batch processing of IPG II and III demands. It was not considered essential to model the communications center activity. The batch autodin processing is contingent upon the arrival of input that may have been waiting in the communication center; on Figure 6-5, a proportional delay will be encountered in Q-nodes 5 and 6.

The input to Q-node 6 shown arriving from Figure 7-7 nodes 100, 105, and 111 consists of mechanized POE input including SERVMART, keypunched IPH III DD 1348s, and Special Program requisitions. The processing of these categories is discussed in Chapter 7. Their inclusion in Q-node 6 models the concurrent processing of autodin and available POE input.

D. THE POE ARRIVAL AND CATEGORIZATION PROCESS

Figure 6-6 depicts the POE arrival and categorization process. Although the analogous autodin process was modeled solely

on IPG considerations, the POE model must account for many additional subcategories. Aside from the addition of categories, the model does not represent a significant increase in complexity.

The POE interarrival process was presented in Chapter 5 and need not be discussed further. Demands arriving at node 14 are probabilisitically routed in relation to the specified category's percentage of Thursday demand. SERVMART replenishment requisitions, averaging 255 per day, represent 6.3% of total daily demand of 4,053 (2551 Hot Line, 550 Provisions, 107 Special Programs IPH II, 590 Special Programs IPH III, and 255 SERVMART). Provisions represent 13.6% and Special Program IPG II and III demands account for 2.6% and 14.5%, respectively. That consumes 37% of the daily average and leaves 63% to be distributed among the Hot Line POE IPGs. The Hot Line weekly average percentages by IPG are 5.64% (I), 57.14% (II), and 37.22% (III). These values are indicated on the applicable branches leaving node 22. As mentioned, this apportionment applies to the 63% of the input leaving node 14. The mechanization split of 70% nonmechanized and 30% mechanized and the assignment of keypunch service times occurs at nodes 15, 20, and 21 <u>before</u> the Hot Line IPG branching at node 22. This sequencing models the assumption that the mechanization percentage is constant across all IPGs.

All categories except Hot Line simply have the appropriate attribute values assigned at regular nodes 16 through 19 and are forwarded to Q-node 25 to await the messenger modeled by

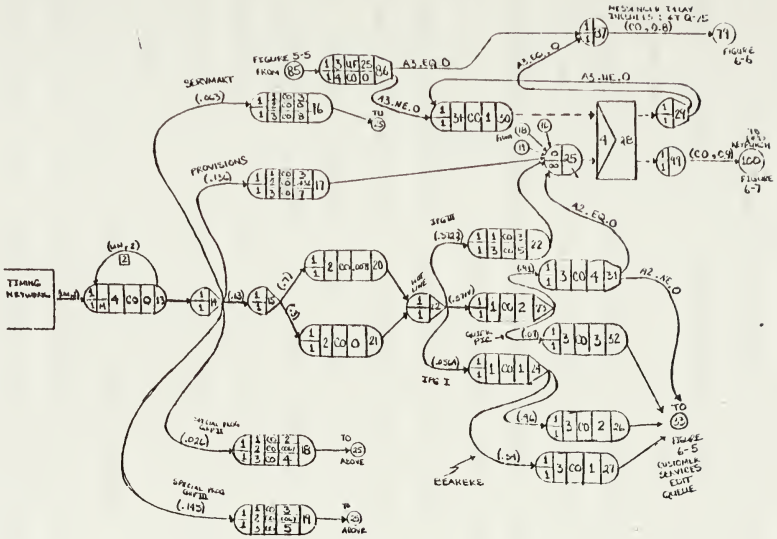


Figure 6-6. POE Arrival and Categorization Process

the nodes 28, 29, 30, 86, and 87 logic. Special Program demands, being identifiable by their keypunch value assignment of 0.0067, were not assigned distinct attribute 3 values at nodes 18 and 19; the values assigned correspond to the autodin IPG II and III attribute 3 designators shown on Figure 6-5. All Hot Line IPG IIIs and mechanized IPG IIs are also shown going directly to Q-node 25. This branching deviates from reality in the sense that all POE Hot Line input is counted and edited in Customer Services. However, mechanized IPG IIs and all IPG IIIs usually arrive in batches and are necessarily afforded an extremely cursory edit of a duration that is insignificant with respect to time awaiting the messenger. Therefore, these requisition categories will bypass the routing through Customer Services editing before arriving at Q-node 25. To compensate for the reduced edit queue input; the number of servers performing the edit function, which was specified as 2 in the reference (b) study, will be limited to 1.

Hot Line IPG IIs are proportioned into the QUICK PIC (9%) and Table 5-1 Other (91%) categories at node 23. The QUICK PIC percentage was computed using an average daily input of 162 and dividing this value by the average Hot Line IPG II input over the entire week; therefore, this percentage will not change as the day of the week changes in the completed model. The remaining 91% of the Hot Line IPG II input is conditionally routed at node 31 based on the keypunch service time attribute. Those that do not require keypunch are forwarded to Q-node 25 and will be batch processed in DPD. The remaining

IPG II requisitions leaving node 31 are routed to Customer Services to be edited, keypunched, and put in-process. All QUICK PICs, mechanized or not, are sent to Customer Services. IPG I demands are divided into Bearers and Others at node 24, assigned a processing priority designator (attribute 3) at nodes 26 and 27, and forwarded to Customer Services. The Bearer percentage was developed from Table 5-2.

Figure 6-6 indicates that SERVMART Replenishment requisitions and QUICK PIC arrive uniformly over the day. In actuality, the SERVMART operation at NSC San Diego is a mechanized system called EPOS (Electronic Point of Sale) which generates a daily replenishment tape that is forwarded to DPD for overnight/weekend processing. Therefore, the mark time for the SERVMART replenishments will be premature. However, it will be on the correct day and be more indicative of the actual delay between real time reorder recognition and the subsequent replenishment issue. QUICK PIC, as described in Chapter 5, is a system featuring the submission of requisitions at designated area locations. They are picked up and delivered to Customer Services during the day shift, but are usually not processed until the second shift. Therefore, the model assumption of uniform arrival rate over the day shift followed by processing on the second shift does not introduce a significant distortion of reality.

It was stated that the percentages indicated on the branches leaving node 14 represented daily averages as a percentage of total Thursday demand. Consequently, as the model is stepped

through the week, these percentages should change. However, in actual model operation these values will remain constant and only node 13 and the interarrival logic associated with it will be revised/replaced. This procedure will theoretically result in the volume of special category (Provisions, Special Programs, and SERVMART) demands varying proportionally with the daily level of demand as defined by the interarrival distribution. This appears sufficient in view of the Chapter 5 discussion of the nature of the special category statistics.

The messenger logic associated with Q-node 25 represents the continuation of the routing that was initiated at node 83 on Figure 6-5. The logic is identical to the autodin IPG I transfer network. The contents of Q-25 are forwarded from node 99 to DPD keypunch node 100 after encountering the indicated delay. When Q-node 25 is empty, AT 3 = 0, the messenger departs from node 87 and proceeds to node 70 on Figure 7-6 to pick-up IPH I issue documents destined for the Broadway warehouse complex.

VII. CUSTOMER SERVICES AND DPD KEYPUNCH

A. Q-GERT RESOURCES

Prior to discussing the Customer Services model segment, the concept of Q-GERT resources must be introduced. Figure 7-1 portrays a keypunch queue and service activity containing two identical servers.

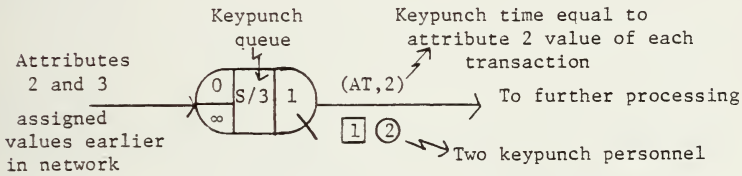


Figure 7-1. Simple Queue and Service Activity

As servers become idle, transactions are removed from Q-node 1 and placed in service for a period equal to the transaction's attribute 2 value. Transactions are ranked in the Q-node based on their attribute 3 value with the smallest value first. This simple network will perform the keypunch function and automatically be included in the Q-GERT Program statistical output. Average transaction waiting time in Q-node 1 and the percentage of time each server is busy are among the statistics generated. This approach would be both efficient and sufficient for describing a single or double shift operation as long as the number of servers remained constant. However, the second shift at

NSC San Diego has fewer personnel at all work stations that remain active. Therefore, a procedure to model a change in the number of servers at a given point in time is needed. Q-GERT concepts previously introduced do not provide this capability although it may be possible, with a great degree of difficulty, to devise a user function that will do it. Thus, the concept of replacing the server(s) in a network segment with a variable resource allocation scheme is illustrated in Figure 7-2.

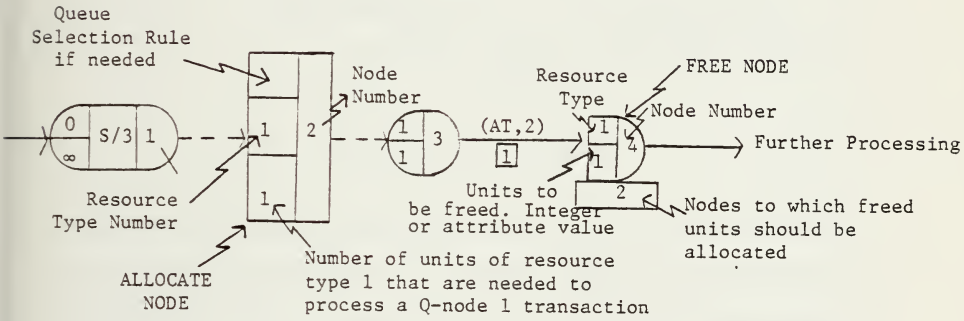


Figure 7-2. Allocate and Free Nodes

Subject to initializing conditions that will be presented later, the Figure 7-2 network performs the same function as the Figure 7-1 symbology. The resource type specified on the left side of allocate node 2 implies that resources must be categorized and numbered in accordance with the function they perform. If Q-node 1 contains documents to be keypunched, then resource type 1 must have a keypunch capability. This same

resource could, however, be used elsewhere in the network for dissimilar tasks if appropriate. A RES (Resource) card is used to define each type of resource, provide the initial system capacity, and list the allocate nodes associated with the resource type. The following format could be used to describe the Figure 7-2 network:

```
RES, 1/KEYPNCH, 15, 2, 7, 8 *
```

Type — Descriptive Label for Output — Initial number of keypunchers — Allocate nodes associated with this type resource

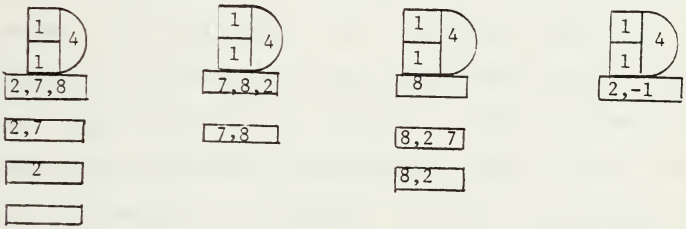
Resource Card Example

This resource designation could apply if it was determined that keypunch personnel in Customer Services and DPD were undistinguishable. There may be 15 day shift keypunchers, 2 in Customer Services and 13 in DPD, processing transactions from the Q-nodes preceeding Customer Services allocate node 2 and DPD allocate nodes 7 and 8. If the type 1 resource were limited to Customer Services keypunchers working only on transactions in Q-node 1, the 15 would be changed to 2 and the allocate nodes limited to node 2 only.

Returning to Figure 7-2, the allocation of a resource, when available, to a transaction in Q-node 1 effectively "captures" that resource and routes it with the transaction until a free node is encountered. Therefore, a resource would flow with a

requisition through node 3, encounter a delay equal to the transaction attribute 2 value, and then be released and returned to allocate node 2 by free node 4. The resource remained captured, and thus unavailable, for the same period of time a Figure 7-1 server would be busy.

Consider the situation described on the illustrated RES card example. DPD and Customer Services keypunchers were assumed interchangeable. Free node 4 might then have been displayed in one of the following ways with the indicated allocation scheme:



Free Node Allocation Examples

The multiple allocation designations under the three leftmost free nodes are provided to illustrate that each vertical grouping describes an identical reallocation scheme. The 2,7,8 allocation on the leftmost node is identical to the RES card order and specifies that allocate nodes 2, 7, and 8 should be reviewed in that order for the possible allocation of freed resources. However, the three allocation schemes directly

below the [2,7,8] indicator provide the same allocation order because all RES card allocate nodes not shown under the free node will also be screened in the RES card order. Therefore, the blank entry indicates the RES card order should be followed. The [2] and [2,7] schemes achieve the same effect because the remaining allocate nodes using Type 1 (keypunch) resources would be reviewed in the order specified on the RES card.

The second and third free nodes illustrated provide examples that again screen all three allocate nodes using resource type 1 but specify a different allocation order than the RES card. The effect under each free node is the same due to the automatic inclusion of the remaining RES card nodes. The right-most free node, however, will reallocate only to allocate node 2. The specification of the negative value eliminates the RES card review and limits reallocation attempts to the ordered sequence of allocate nodes preceding the negative value at the free node. Therefore, the designation [8,2,-1] results in an attempt to apply freed resources at allocate node 8. Any remaining resources would then be applied to allocate node 2 if they were needed there. If freed resources remained after sequential allocations at nodes 8 and 2, they would become inactive rather than applied to node 7.

Any transaction can be used to initiate the freeing of resources up to the RES card capacity at a free node. In particular, the arriving transaction need <u>not</u> have resources allocated to it. If the number of resources to be freed is greater than the number idle, the quantity of busy resources necessary to

equal the freed quantity will immediately be idled. Therefore, if these busy resources are functioning in a server capacity, they will immediately "leave their transaction" and prohibit the modeler from interpreting resource utilization output as identical to server statistics.

Figure 7-3 illustrates a modeling scheme that would be particularly relevant to stock point operations.

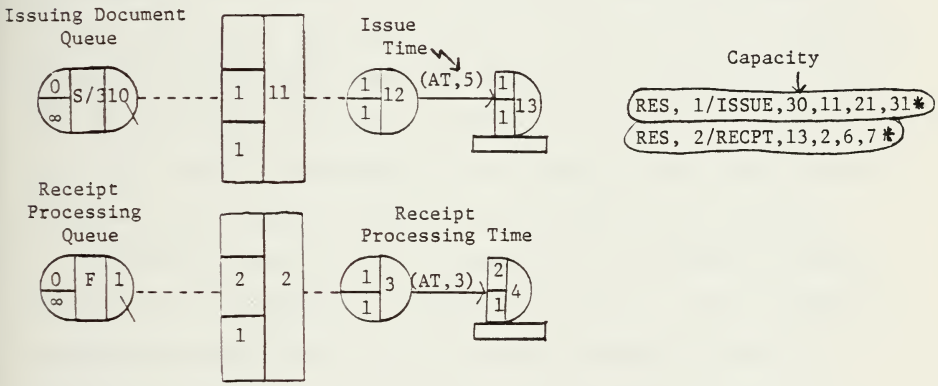


Figure 7-3. Issue and Receipt Processing

As defined on the RES cards, personnel processing issues are categorized as a different type of resource than receipt processors. The RES card also illustrates that there are additional issue processing network segments using allocate nodes 21 and 31. The blank allocation block under free node 13 indicates the RES card sequence will be followed when allocating freed

resources. The free nodes associated with allocation nodes 21 and 31 may have allocation schemes of $\boxed{21,31,2}$ and $\boxed{31,2,21}$, respectively, Using that scheme, all resources would "remain in place" as long as there were issues to be made. The receipt processing network would function in a similar manner although the receipt processing capacity is 10 (from the RES card) as compared to 30 issue resources.

Realistically, these two types of resources are interchangeable and a capability to transfer reousrces between the receipt and issue functions exists. Figure 7-4 is a simplified version of the Q-GERT symbology effecting a conditional transfer of resources based upon backlog consideration. This example will serve to introduce the AL (Alter) node, which is used to change the resource capacity specified on the RES card.

At node 30, an arriving transaction is assigned an attribute 1 value computed by UF (User Function) 7. This FORTRAN subprogram would examine the issue and receipt Q-nodes to determine whether resources should be transferred from issue to receipt processing (A1 = 1), receipt processing to issue (A1 = 2), or remain as assigned on the RES card (A1 = 3). A second user function, which is designated UF8, will compute the number of resources to be transferred and assign that value to attribute 2 of the transaction. The conditional-take-first branching from node 30 is based on the attribute 1 value assigned and, if the user functions indicate that resources should be shifted from issue (Type 1) to receiving (Type 2), the upper branch will be taken. Alter node 40 will reduce the Figure 7-3

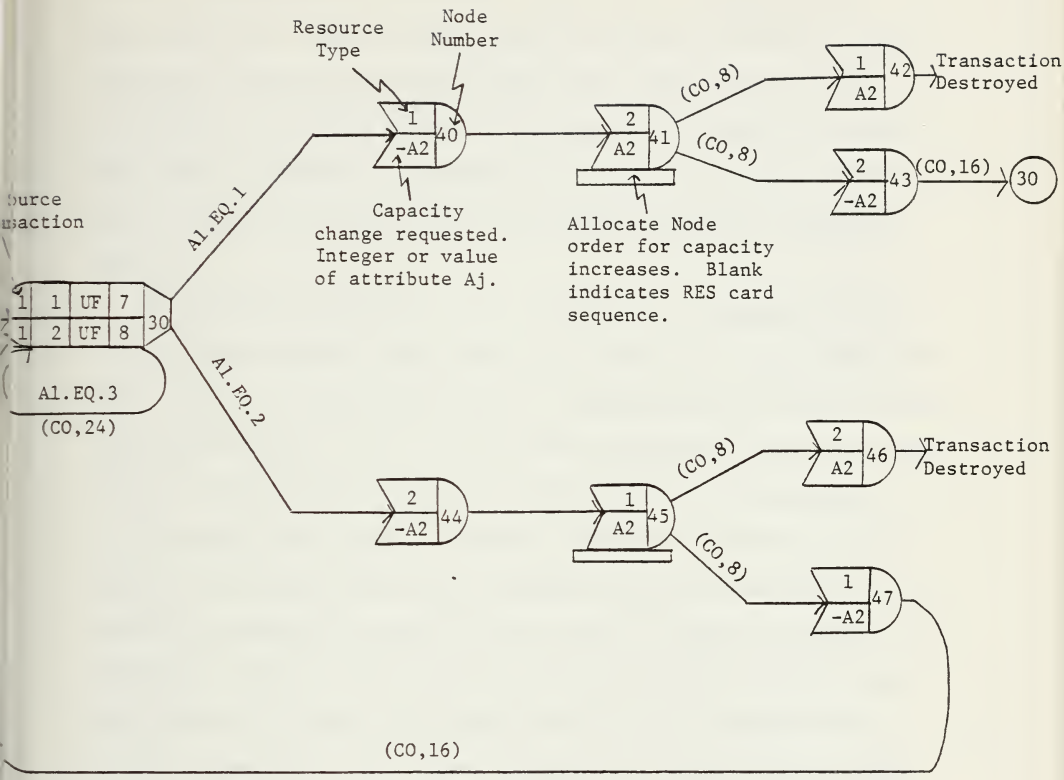


Figure 7-4. Alter Node Network

RES card capacity of 30 by the value of attribute 2 of the arriving transaction. However, unlike the free node, the alter node will wait until resources are idle before seizing them. Alter node 41 will then increase the receiving resources by A2 units and allocate them as specified on the RES card and

described in the free node discussion. The eight hour delay on the deterministic branching from node 41 indicates the resources will remain reassigned the entire workday and then altered to equal the original RES card capacities at nodes 42 and 43. The transaction leaving node 42 departs the system; node 43 output is assigned a 16 hour delay then routed back to node 30 to initiate the backlog evaluation process again.

The second branch (A1 = 2) operates in a similar manner but transfers assets from receiving (Type 2) to issue for the day. If it is determined that no resource shifts are required, the bottom branch (A1 = 3) is taken from node 30 and a 24 hour delay is encountered before the next backlog evaluation.

The applicability of resource capacity altering to the modeling of breaks and shift changes should be apparent. A resource allocation network could even be used to provide a messenger service; the amount of the messenger resource made available by an alter node could be set to a constant value or even equated to the number of queued transactions waiting to be routed. After the routing was completed, the messenger capacity would immediately be altered to zero to preclude the movement of transactions before the next scheduled messenger run.

B. CUSTOMER SERVICES

The Q-GERT representation of the NSC San Diego two shift Customer Services operation is shown on Figures 7-5 and 7-6. Autodin IPG I input from node 84 on Figure 6-5 and POE input

from nodes 26, 27, 31, and 32 on Figure 6-6 are shown entering the edit queue, Q-node 33. Nodes 34 through 36 model the edit server as a resource as described earlier in this chapter. The time to edit, which is indicated by the delay on the branch between nodes 35 and 36, is a constant 0.002 hours (7.2 seconds) as specified in reference (b). The RES card image shown under node 34 indicates there is one unit of the edit resource that, when freed, is to be allocated at node 53, then 34. Node 53, which is part of the second shift exception processing network in the lower left portion of Figure 7-5, is discussed below. During the day shift, the edit resource will be processing requisitions from Q-node 33 only. The free node 36 allocation scheme of 53,34 is identical to the RES card and therefore could have been omitted.

The conditional-take-first branching from node 36 functions to provide special processing for QUICK-PIC transactions. They are modeled as being edited upon arrival and then stored in Q-node 37 until released by a timing network transaction arriving at node 39. Once again the requisition transfer system described in Chapter 6 effects the instantaneous timed release of the QUICK PIC transactions from node 41 to either node 43 if keypunch is required, or to DPD if mechanized (A2.EQ.0). The model will provide the transfer at 1800 on each working day for the following two reasons: (1) QUICK PIC, with an A3 = 3 designator, should be withheld from the keypunch S/3-ranked queue (Q-node 43) long enough to maximize the number of non-mechanized IPG II demands (A3 = 4) placed in-process before

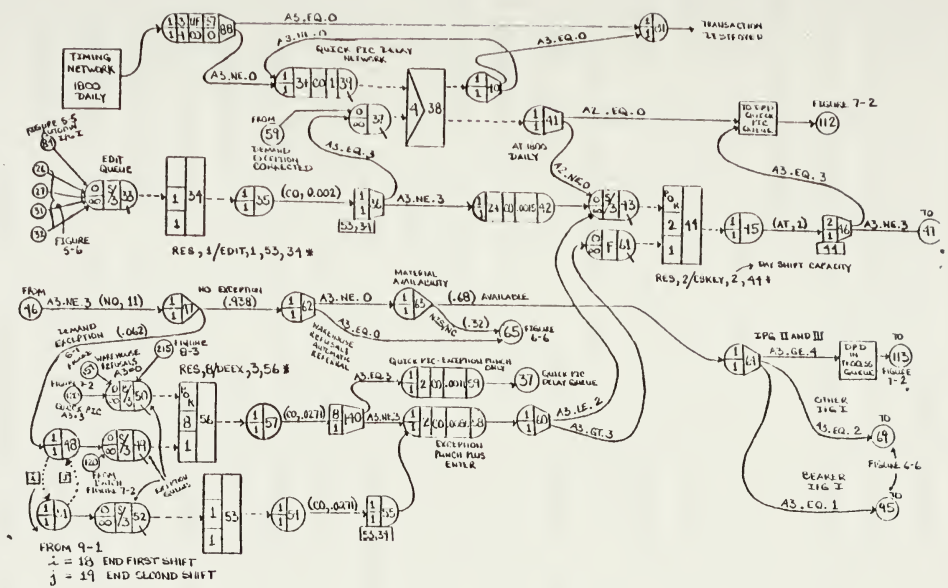


Figure 7-5. Customer Services (Part 1)

the 1800 backorder/in-process release program is run in DPD; and (2) once entering the keypunch queue, the relatively small attribute 3 value should ensure all QUICK PICs are keypunched prior to the end of the second shift. Theoretically, QUICK PIC processing will cease only upon the arrival of an autodin IPG I; POE input terminates at 1600 in the model. A discussion of the IPG II in-process and subsequent release relationship was presented in Chapter 5.

The requisitions routed from node 36 to node 43 via regular node 42 will be Bearers, other IPG Is, and IPG IIs. Each category will not only be keypunched if necessary (A2.NE.0), but will also be entered for remote processing. Since the nodes 44 through 46 resource allocation network performs the joint keypunch and enter action based upon the transaction's attribute 2 value, an entry time of 0.0015 hours, or approximately 5 seconds, is added to the keypunch time at node 42. The transactions are then routed to Q-node 43 where they, and QUICK PICs arriving at 1800, are processed by the CSKEY (Customer Services Keypunch) resources illustrated on the RES card image under allocate node 44. The indicated day shift capacity of two will be reduced to one at 1600 each day by an alter node in the timing network. Note that two Q-nodes, 43 and 61, contain transactions that use Customer Services keypunch resources. Demand exceptions and warehouse refusals for all requisition categories are processed by the Exception Unit and returned to Q-node 43 or 61 for exception keypunch and, except for QUICK PIC, immediate entry. If there are transactions in both Q-nodes,

the queue selection priority scheme located in the upper left partition of allocate node 44 is used to determine the next transaction processed when resources are freed.

Table 7-1, which was reproduced from reference (a), lists the queue selection rules that may be specified at either allocate nodes or S-nodes (Selector nodes). The ASM (Assembly Mode) option listed last in the table may only be used at S-nodes. Allocate node 56 on Figure 7-5 was originally modeled as an S-node. The description of the node 56 demand exception processing network will include an introduction to the use of S-nodes.

The POR (Preferred Order) specification at allocate node 44 was selected as the most realistic option available in Table 7-1. Assume that Q-node 61 was not included and all processed exceptions leaving node 60 were routed to Q-node 43 and ranked as indicated by their attribute 3 value. Since demand exceptions are encountered on all requisition categories except SERVMART and provisions (attribute 3 values from 1 to 5), the large volume of higher priority demands arriving at Q-node 43 could possibly delay the keypunching and reentry of IPG III exceptions for an inordinately long period. In reality, demand exceptions are not processed on a strict priority basis by the Exception Unit. Exceptions often arrive at keypunch batched by type of exception and containing both IPG II and III requisitions. Keypunch, in turn, will process the entire batch sequentially unless interrupted by the arrival of an IPG I. Therefore, requisitions having large attribute 3 values

Table 7-1. Priority rules associated with allocate and S-nodes for selecting from parallel queues

Code	Definition
POR	Priority given in a preferred order.
CYC	Cyclic Priority - transfer to first available Q-node starting from the last Q-node that was selected.
RAN	Random Priority - assign an equal probability to each Q-node that can be selected.
LAV	Priority given to the Q-node which has had the largest average number of transactions in it to date.
SAV	Priority is given to the Q-node which has had the smallest average number of transactions in it to date.
LWF	Priority is given to the Q-node for which the waiting time of its first transaction from its last marking is the longest.
SWF	Priority is given to the Q-node for which the waiting time of its first transaction from its last marking is the shortest.
LNQ	Priority is given to the Q-node which has the current largest number of transactions in it.
SNQ	Priority is given to the Q-node which has the current smallest number of transactions in it.
LNB	Priority is given to the Q-node which has had the largest number of balkers from it to date.
SNB	Priority is given to the Q-node which has had the smallest number of balkers from it to date.
LRC	Priority is given to the Q-node which has the largest remaining unused capacity.
SRC	Priority is given to the Q-node which has the smallest remaining unused capacity.
ASM	Assembly mode option - all incoming queues must contribute one transaction before a processor may begin service (this can be used to provide an "AND" logic operation); S-nodes only.

aren't actually waiting as long as a direct input into Q-node 43 would theoretically cause. This observation indicated that the addition of a second Q-node for exception unit output was advisable. Consideration was given to routing all exceptions to Q-node 61, which would be assigned an S/3 ranking, and establishing a POR (Preferred Order) queue selection rule at allocate node 44 with Q-node 43 as the preferred queue. This procedure would inhibit any processing of node 61 exceptions unless Q-node 43 was empty. The expected volume at node 43 caused the rejection of this approach; a large percentage of incoming requisitions will pass through Q-node 43 while only 6.2% of all demands will encounter exceptions. Similar volume considerations led to discarding an "all exceptions to node 61, LNQ queue selection" approach with an S/3 ranking procedure in the queue. Although this technique would place warehouse refusals and IPG Is (attribute 3 values of 0, 1, and 2) at the head of Q-node 61, it again appeared likely that the high volume in node 43 would preclude the actual expeditious processing afforded warehouse refusals and IPG Is. Therefore, the indicated compromise routing was established. Warehouse refusals and IPG Is are routed on the A3.LE.2 branch to the higher volume queue, node 43, where they are ranked on a "smallest value of attribute 3" basis. This places warehouse refusals, which possess a zero attribute 3 value, first in the queue and models NSC San Diego management policy. The IPG Is, having attribute 3 values of 1 and 2, will therefore be processed directly after the warehouse refusals to reflect the special management attention

given this category by Customer Services. The S/3 ranking in exception processing Q-nodes 49 and 52 also implies a strict priority exception processing procedure is used. While this is always true for the IPG Is and the IPG IIs put in-process at Customer Services keypunch, recall that it is not completely factual for batch processed IPG II and III exceptions arriving at Q-node 49. Therefore, an F (First-In-First Out) queue ranking rule was specified at Q-node 61 to model the actual occurrence of IPG III exceptions being reentered by Customer Services before IPG IIs originating at a later batch run. This modeling approach will partially offset the somewhat erroneous strict priority processing technique used in the Exception Unit.

An LNQ (Largest Number in Queue) designation at allocate node 44 would have modeled a cyclic processing procedure once the queues contained the same number of transactions. This was considered too great a departure from reality. Therefore, the POR option with Q-node 43 preferred was selected despite the much higher volume arriving at Q-node 43. This technique will result in batch keypunch and entry of IPG II and III exceptions on a FIFO basis once the processing of the contents of Q-node 61 begins; i.e., when Q-node 43 is empty. This approach is more realistic than it may appear. The technique used should result in IPG II and III exeptions begin batch processed on the Customer Services evening shift, which is precisely what actually often occurs. The foregoing discussion emphasizes the complexity of the exception processing/Customer

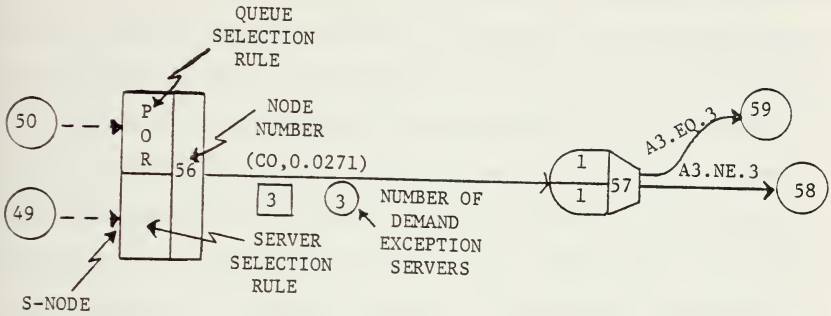
Services keypunch relationship and presents the myriad factors that entered into the modeling decision.

Returning to Figure 7-5 at free node 46, the keypunched QUICK-PIC requisitions, which were not entered by Customer Services, are removed and forwarded to a special DPD queue. The remaining transaction are assessed a variable delay prior to node 47 to represent remote processing time. Although entering a requisition frees the keypunch resource, the transaction is delayed until processing is completed. Activation of the on-line remote demand processing program is based upon time-volume considerations. Requisitions entered through remote terminals are queued and processed at six minute intervals unless 30 transactions accumulate before the time expires. Nevertheless, delays in the receipt of a response (issue document, referral, or exception) that exceeded 15 minutes were frequently observed. Lengthy delays were probably attributable to time awaiting the issue document punch routine, a relatively slow operation when compared to CPU processing times. In additiona, two minute turnaround times were noted during low workload periods when a six minute wait could reasonably be expected. Therefore, the processing time assigned at node 42 will be taken from a normal distribution having a mean of eight minutes and a standard deviation of 2.5 minutes. Minimum and maximum processing times of two and 17 minuts are also specified.

The branching from node 47 models the 6.2% demand exception rate developed in Chapter 5. During the day shift, exceptions

occurring from Customer Services remote entries will be routed through node 48 to Q-node 49 where, via allocate node 56, three type 8 resources (servers) are available to process them at the reference (c) DIMES rate of 0.0271 hours (1.626 minutes) per transaction indicated between nodes 57 and 140. The POR designation at allocate node 56 gives Q-node 50 processing priority over Q-node 49. Therefore, exception processing on all requisition categories in Q-node 49 - from both remote and batch input - is delayed until the QUICK PIC demand exceptions and warehouse refusals residing in Q-node 50 have been completed. While this approach may appear to introduce an unacceptable delay on IPG I and II transactions residing in Q-node 49, the relatively small expected volume in the priority queue should eliminate any extraordinary delays. QUICK PIC exceptions, which can be epxected to occur at a 6.2% rate on less than 200 transactions per day, will <u>all</u> appear at the head of Q-node 50 at the beginning of each working day and immediately be processed when resources become available at 0730. Warehouse refusals, on the other hand, not only occur at a relatively low 1% (of issues) rate, but are also routed by messenger with nearly two hours between scheduled arrivals. Therefore, with three exception processing resources available, considerable attention will be given to Q-node 49 exceptions in the period between warehouse refusal arrivals. The B/3 ranking scheme at Q-node 50 ensures that QUICK PICs, with the bigger attribute 3 value of 3, are processed before warehouse refusals.

The network segment consisting of nodes 56, 57, and 140 was originally modeled using the S-node logic shown below.



The POR designation in the queue selection partition functions exactly like the identical specification in an allocate node. Any of the queue selection rules listed in Table 7-1 can be used with an S-node. In addition, a server selection priority rule may be specified in the lower left partition if a choice between dissimilar servers must be made. Since the S-node above routes transactions to three identical demand exception servers at the activity designated number $\boxed{3}$, no server selection rule was required. Chapter 5 of reference (a) details numerous modeling enhancements that can be realized through the use of various permutations of the queue and server selection rules.

The S-node approach was discarded because the servers could not be removed or reduced when the shift ended. Therefore, the processing of backlogged transaction in Q-node 49 will continue during the evening and midnight shifts until the queue is empty. This condition invalidated the S-node approach; exceptions

remaining in Q-node 49 at the end of the normal working day will not be processed until the servers become available again the following day. Therefore, a resource allocation approach, which permits the application and removal of resources from the timing network, was adopted to replace the S-node network.

After an exception has been processed, it is routed to free node 140 where the exception processing resource is freed and the indicated branching occurs to preclude assigning an entry time to QUICK PIC transactions. The time to keypunch an exception is assumed to equal the standard requisition keypunch time of 0.0071 hours. Following the node 58 or 59 keypunch processing time assignment, the previously mentioned node 60 conditional branching to the Customer Services queues occurs. QUICK PICs encountering exceptions are <u>not</u> expedited in an attempt to make the 1400 deadline. Upon discovering that his material is not available for pick-up, the customer has the option of coming in and obtaining the material as a Bearer or waiting an additional 24 hours. Actually, the QUICK PIC exception would be processed before queuing for the late evening transfer to DPD. However, sending it to Q-node 37 and clearing the exception after 1800 introduces no erroneous delays while eliminating the need for more complex branching.

The foregoing discussion applied to day shift exception processing. If an exception occurs on a requisition entered by the Customer Services second shift, it will be transfered from node 48 to node 51 by means of a Q-GERT technique called

nodal modification. The symbology shown between nodes 48 and 51 can be interpreted in the following way:

- Upon completion of activity i, which will be an 8.5 hour delay in the timing network to represent the day shift, node 51 will replace node 48.
- Node 51 will remain in the network until activity j has been completed to signal the end of the second shift.

While node 51 is in the network, transactions (exceptions) arriving at node 48 will be rerouted to node 51 and forwarded to Q-node 52, the second shift exception processing queue. Allocate node 53 indicates that resource type 1 is used to correct the exception. Free node 55 attempts to reallocate freed resources at nodes 53 and 34, which follows Q-node 33, the edit queue. Free node 36 of the edit resource network also attempts to reallocate at node 53 first. During the day shift, an allocation at node 53 will not be made because Q-node 52 will be empty; i.e., no exceptions are being routed there until after 1600. However, during the second shift, editing of Q-node 33 will terminate when an exception occurs because the edit resource, when freed at node 36, will be allocated to the exception first. The model is realistic. Editing is interrupted to process exceptions occurring, in general, on autodin IPG Is and IPG IIs being put in-process. Of course, requisitions and exceptions remaining in Q-nodes 43 and 63 after the day shift are also being keypunched and/or entered. The routing from node 55 need not incorporate the QUICK PIC consideration modeled

by node 57; QUICK PICs are not entered from Customer Services by remote and all exceptions originating in the special QUICK PIC overnight batch run arrive at Q-node 50 each morning.

Requisitions branching without exception from node 47 are first subjected to the conditional branching at node 62 where Warehouse refusals are removed. The existence of a warehouse refusal indicates that material was not available and, theoretically, the modeled referral will automatically occur. In practice, material sometimes does become available from a variety of sources. However, no attempt will be made to model the numerous factors that can invalidate a warehouse refusal. The NSC San Diego February 1980 material availability or POE (Point of Entry) effectiveness percentage of 68% is applied at node 63. Requisitions branching as not available (referrals) are routed to node 65 on Figure 7-6 along with the referrals originated by warehouse refusals. Requisitions that can be satisfied are routed to node 64. All IPG II and III demands are sent to the DPD in-process queue where they will be released at 1800 daily. Although no IPG IIIs entered Customer Services at the edit queue, they do arrive as exceptions which, when corrected, are put in-process by keypunch resources. IPG Is branch from node 64 as either Bearers or Others due to the distinct processing differences shown in Figure 7-6.

As indicated by the branching from nodes 69 and 95 on Figure 7-6, it will be assumed that 15% of all demand (provisions excluded) is for material warehoused at the National City complex. The remaining 85% is lodged against assets at the

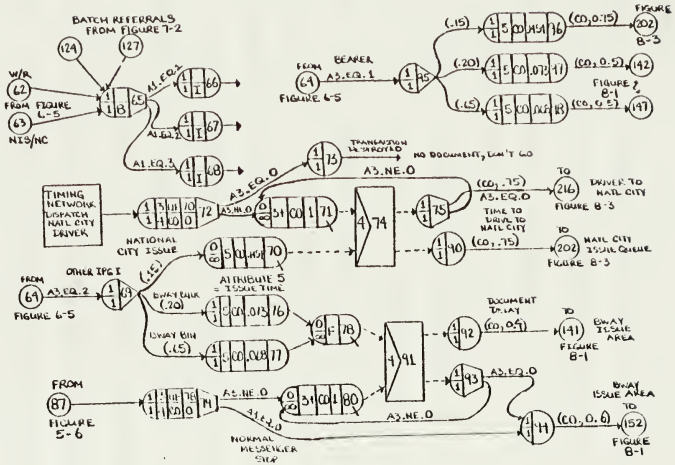


Figure 7-6. Customer Services (Part 2)

Broadway location with bin and bulk material contributing 65% and 20%, respectively. The IPG Is were subcategorized at node 64 (Figure 7-5) prior to the location designation to ensure each subcategory would be assigned a representative National City issue percentage. A separate messenger service transports non-Bearer IPG Is to National City. The network representing this document flow consists of nodes 70 through 75 plust 90 on Figure 7-6. Although it is not included in the model, an IPG I processing idiosyncracy should be mentioned; all IPG I issue documents, Bearer or Other, are printed and output at Customer Services (Broadway) regardless of the material location. There is a remote terminal at National City through which requisition entry is initiated. However, even if an IPG I request for National City material were entered there, the issue document would have to be obtained from Broadway (Customer Services) and transported back to National City by the Bearer or messenger. Since National City entry workload is included in the reference (e) totals and all IPG I issue documents originate in Customer Services, a separate National City entry station in the model was not considered necessary. The existing NSC San Diego procedure introduces IPG I processing delays for National City material. Bearers may encounter a delay equal to the time of a round trip to National City. Other IPG Is for National City material will normally be entered at Broadway and will experience a delay that depends on the timing of the next National City messenger run. Therefore, the only delay missing in the model is the Bearer travel time from

National City to Broadway; i.e., a Bearer entered at National City for National City material. This omission is not considered crucial; travel time (30-45 minutes) is concurrent with the entry and document preparation time that, as discussed above, is normally distributed with a possible maximum of 17 minutes.

Following the issue category determination at nodes 65 and 95, identical DIMES issue time standards are assigned as attribute 5 to Bearers at nodes 96 through 98 and to Other IPH Is at nodes 70, 76, and 77. The Broadway bin issue time of 0.068 hours is a hot line issue time in contrast to the lower AMHS (Automated Material Handling System) bin issue time of 0.45 hours for requisitions lotted in DPD. An IPG I bin issue functions as an interrupt to AMHS lotted, location sequenced bin issues. This random deviation from the lotted location pattern will normally increase the issue time.

The constant delays on the branches from nodes 96 through 98 represent Bearer travel times to the appropriate warehouse. The network associated with match node 74 represents the National City driver/messenger. The logic for removing the transaction(s) from Q-node 70 is identical to the Chapter 6 messenger description. However, this messenger will always be dispatched from the timing network and, as shown on the branch from node 73, the trip will <u>not</u> be made if there are no IPG Is to take. Since the messenger will return from National City with warehouse refusals, a portion of them may also experience a longer delay than usual.

The match node 91 messenger will be arriving from the Figure 6-6 node 87 network during the day shift. Since this is the regular message service, the trip to the warehouse via node 94 will be made regardless of the status of Q-node 78. The second shift messenger runs, while less frequent, will include all stops made on the day shift. However, they will be initiated from a distinct network timing segment to facilitate revisions in subsequent versions of the model. For example, decision logic to inhibit messenger travel if Q-node 78 were empty could be incorporated into the disjoint timing network on Figure 10-3.

The final Figure 7-6 network segment to be discussed is the referral statistics summary performed by nodes 65 through 68. Batch and POE referrals plus warehouse refusals are routed to node 65 for a time between referrals computation. The Q-GERT analysis Program will provide a histogram of interarrival times based upon user defined cell divisions as specified on the the STAtistics node 65 input card. Similar histograms for Interval statistics will be generated at nodes 66 through 68. The branching from node 65 splits the referrals into IPG I through III requisitions. Interval statistics refer to the time between the last requisition mark time, which is the arrival time in the model, and the arrival of the transaction at the node effecting the collection of interval statistics. Had attribute 3 been used to distinguish between autodin and POE demands within each IPG, separate referral statistics could have been maintained on each major category. This enhancement

would be particularly useful if autodin IPG referrals could be isolated during input categorization and assigned a distinct attribute value. First, since these transactions have already been referred by the POE stock point and rerouted by the ICP, the allowable processing time is decreased. Finally, the ICP rerouting was initiated based on visibility of the NSC San Diego asset position through the TIR (Transaction Item Reporting) process. Therefore, a subsequent NSC San Diego referral on this type of transaction either indicates a record discrepancy or is prompted by the real time lag in the TIR procedure.

It must be emphasized that the referral statistics collected at nodes 65 through 68 were specified by the node input cards and represent the most elementary statistics gathering technique available in Q-GERT. An entire chapter in reference (a) is devoted to the collection of user designated statistics by means of program inserts accessing established Q-GERT subroutines. Therefore, the complexity of the statistical output is a modeling decision that is not limited to the standard statistics node options of First release, All releases, time Between releases, Interval times, and Delay from first arriving transaction to nodal release. The latter designation would be of interest only if transactions were being accumulated before being released.

C. DATA PROCESSING DEPARTMENT KEYPUNCH

The processing taking place in DPD keypunch is presented in Figure 7-7. Requisitions are transported by messenger from node 99 on Figure 6-6 to regular node 100. Arriving

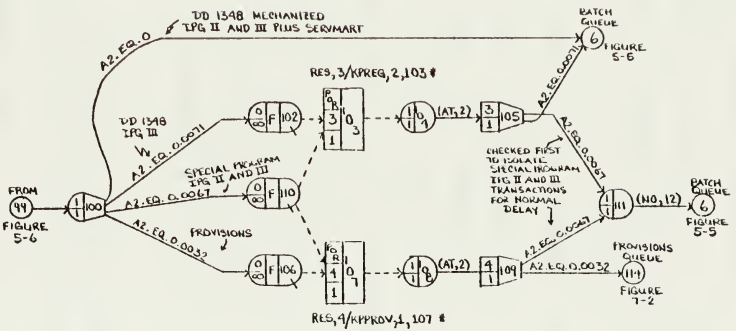


Figure 7-7. DPD Keypunch

transactions include SERVMART, Special Programs, Provisions, POE IPG II mechanized 1348s, and all POE IPG III demands. That is, requisitions from all categories routed to Q-node 25 on Figure 6-6 are delivered by messenger to node 100 where the indicated conditional branching occurs.

All mechanized input is branched from node 100 to Q-node 6, the batch processing Q-node from Figure 6-5. Therefore, all mechanized input including SERVMART replenishment requisitions will be processed during the next scheduled batch run after their arrival. This treatment of SERVMART replenishments is erroneous in that the entire replenishment tape is actually processed during the same batch run. However, since SERVMART requests will subsequently be delayed a day by Production Planning, the overall time in the system will not be increased through the multiple batch technique used. As mentioned in Chapter 6, it was the choice of a modeling technique through which SERVMART replenishments arrive periodically during the day rather than all at once that leads to an increased time in the system for this demand category.

Nonmechanized DD 1348s, all Special Program requests, and provisions demands are segregated at node 100 and sent to Q-nodes 102, 110, and 106, respectively, to await the availability of DPD keypunch resources. DD 1348s from Q-node 102 will be processed in the resource allocation network consisting of nodes 103 through 105. As indicated on the RES card image above allocate node 103, two type 3 resources designated REGKP will be available to keypunch DD 1348s. Similarly, one type 4 PROVKP resource has been provided to keypunch provisions

requests in the nodes 106 through 109 network segment. The output symbology on the Special Programs queue, Q-node 110, indicates that either resource type 3 or 4 will keypunch these requests. However, the POR designator on allocate nodes 103 and 107 will prohibit the processing of Special Program requirements by either resource type until the respective preferred Q-node, 102 or 106, is empty.

The three keypunch resources specified on Figure 7-7 will be active on the day shift only. The indicated modeling approach leads to the continuous processing of a particular demand category prior to shifting resources to a different input type. A punch-to-disk system featuring the establishment of a distinct record content format for each input category is used during actual operations. Therefore, once a specific format has been established, requests corresponding to that format are sequentially keypunched until management, or the absence of additional input, mandates a shift to a different input type. No attempt has been made to model the management perogative mentioned above. However, it is assumed that the approach used will permit batch keypunching of Special Program requests due to the periodic, vice continuous, arrival of requisitions by messenger.

Reference (b) allotted four DPD keypunch operators. Based upon the Appendix C workload summary, an initial allocation of three personnel to keypunch and verify has been established. The provisioning resource was purposely categorized as a distinct resource type to model the special attention that provisions

actually receive. DPD keypunch resources will be removed for a 1.5 day period every other week to model the existing payroll processing interrupt. This resource removal, as well as all other resource altering actions, will be initiated in the timing network. It should be noted that a resource allocation scheme similar to the issue/receiving example presented earlier in this chapter could be used to alter DPD keypunch resources based on the volume in Q-nodes 102, 106, and 110.

After keypunching is completed, Special Program requests, both IPG II and III, are routed from free nodes 105 and 109 to node 111. The delay initiated on the branch leaving node 111 represents the standard program pricing delay experienced by all Special Program transactions. Based upon the limited information available to quantify this delay, a normal distribution having a mean of 7.5 days, a standard deviation of 1 day, a minimum of 5 days, and a maximum of 10 days was chosen as representative of a pricing cycle that "may take up to 10 days" to complete. Note that the reference (e) reports indicated a daily average of approximately 100 IPG II Special Program requests over the five month data base. <u>If that count is accurate</u>, the 5-10 day delay experienced by these transactions would obviously severely hamper NSC San Diego's efforts to meet the IPG II response times specified in reference (d).

Keypunched DD 1348s and provisions leave free nodes 105 and 109, respectively, for input to DPD batch processing. The DD 1348s are routed to Q-node 6 on Figure 6-5 where they will be processed during the next scheduled batch run. Provisions

are routed to Q-node 114 on Figure 8-2 and held until the next special 1800 batch provisions run occurs.

VIII. DATA PROCESSING DEPARTMENT BATCH PROCESSING AND LOTTING

A. DPD FUNCTIONAL OVERVIEW

Figure 8-1 summarizes the requisition categories awaiting either routine or special batch demand processing in DPD and presents a block diagram overview of the events transpiring during DPD operations. This figure is not to be interpreted as a formal part of the Q-GERT network. It is provided solely to facilitate the explanation of the DPD functions prior to the introduction of the formal network symbology in Figure 8-2. Therefore, Q-nodes 112 through 114, which appear for the first time in Figure 8-1, will be repeated on Figure 8-2.

Q-node 6, which may be considered the routine batch processing input queue, and match node 10 are repeated from Figure 6-5. All requisition categories except QUICK PIC, Provisions, and POE IPG II requests put in-process in Customer Services await FIFO priority batch processing in Q-node 6. Requisitions will be released from Q-node 6 and processed when matching transactions from the Figure 6-5 Q-node 11 messenger network are generated. As previously mentioned, the routine batch processing of Q-node 6 transactions occurs seven times each day with the first run scheduled at 0330 and the finale at 2200. Nevertheless, the model routine batch processing schedule will consist of six runs beginning at 0700 each working day and every three hours thereafter. Issues other than IPG I originated by the 0330 run will not be processed that same day. Therefore, no additional issue delay is being added by the revised schedule.

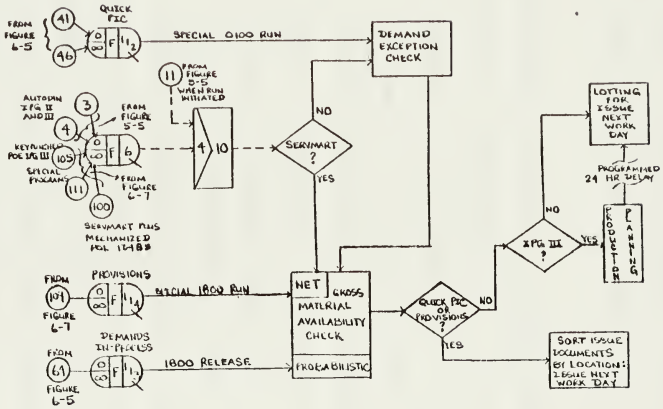


Figure 8-1. DPD Functional Overview

The number of routine batch runs was reduced to six not only to facilitate the network timing, but also to circumvent the somewhat enigmatic, and unexplained, scheduling of a 1000 special batch run right after a routine 0930 effort that processes available POE input along with the autodin traffic. Finally, it must be noted that the model schedule can delay referrals as much as 3.5 hours by virtue of rescheduling the 0330 run until 0700.

The basic functions performed in DPD are demand exception generation, material availability determination, and, if available, subsequent sorting, lotting, and Production Planning manipulation of the issue documents (or issue document image). However, each requisition category is afforded a somewhat different processing technique; Figure 8-1 illustrates the functions that apply to the various demand categories.

The SERVMART decision block in the middle of the figure functions to exclude this type of transaction from a demand exception check in accordance with the rationale presented in Chapter 5. Therefore, SERVMART requests join Provisions and In-Process demands leaving Q-nodes 114 and 113 in the block designated availability check. The omission of a demand exception check for Provisions was also discussed in Chapter 5. In-Process transactions have already been checked for exceptions during Customer Services processing (Figure 7-5).

Although it is not shown on the overview, requisitions having a demand exception will be routed to the exception processing unit in Customer Services where QUICK PICs exceptions

will be given expedited processing at Q-node 50 (Figure 7-5). All other batch exceptions will be given routine, but prioritized, processing at Q-node 49. The detailed network symbology for demand exception generation is presented in Figure 8-2.

All transactions are shown being checked for availability on Figure 8-1. However, the availability block is subdivided into three distinct applicable rates. SERVMART and Provisions are assumed to encounter a net availability rate. In general, SERVMART material is backed-up by main supply stock in accordance with standard SERVMART operating procedures. There are exceptions to this policy, but the model assumption specifies a 100% back-up. Similarly, Provisions requests are generally submitted on partially completed DD 1348s that are prepunched by NSC San Diego. Therefore, the model assumption is that the prepunched requisitions apply to carried material only. All remaining demand categories except In-Process transactions will be referred at the 32% NIS/NC (gross) rate used in Customer Services on Figure 7-5.

Demands put in-process in Customer Services are shown entering the section of the availability block labeled probabilistic. This designation was chosen to indicate that the assets that were available when the transaction was put in-process may no longer exist. The in-process quantity for a particular line item may exceed the number of units on-hand at the 1800 release of these transactions. It was noted that transactions are put in-process based solely on the on-hand quantity in file; i.e., there is no visibility of any quantity already placed

in-process. Furthermore, the asset position upon which the in-process decision was based may have changed due either to the receipt of additional material or the reservation of assets during batch processing. The latter event, of course, is most relevant for attempting to determine whether sufficient material remains available to satisfy the in-process quantity. Unfortunately, any attempt to estimate a reasonably accurate availability rate for the in-process release procedure would require a line item, vice system, analysis that is well beyond the scope of this study. Therefore, having emphasized both the analytical complexity of the process and, more importantly, the impact of the current processing technique on IPG II availability and issue time, the problem will conveniently be ignored by the model. It will be assumed that assets are still available for in-process transactions and, as illustrated on Figure 8-2, these requests will <u>not</u> be subjected to an availability check at the time of release.

The functions appearing on Figure 8-1 after the availability check may be regarded as occurring once each day on the midnight shift and serving to create and arrange the issue documents that will be processed the next morning. Provisions and QUICK PIC requests are batch processed during special runs at 1800 and 0100, respectively. The issue documents for these categories are subsequently sorted by location and forwarded to the appropriate warehouse for issue. Other IPG III requests including SERVMART replenishments are entered in a Production Planning Holding File and delayed for one working day. This procedure

was instituted in recognition of holding area space constraints. It proves much jore efficient to program an unavoidable 24 hour delay as a filed issue document image rather than an actual material issue backlog in the warehouse and delivery staging areas.

IPG IIIs that have completed the programmed delay and the remainder of the non-QUICK PIC IPG IIs are shown entering the lotting block on Figure 8-1. The lotting procedure is a complex process that functions to establish the issuing sequence for the total transaction input. Some, but by no means all, of the lotting and issue procedures currently in effect at NSC San Diego may be summarized in the following manner:

- The sorted QUICK PIC transactions are the first issues processed at the beginning of the work day.
- All other IPG II issue documents are lotted together in the next LOT(s) and represent the first <u>new</u> material issued after QUICK PIC.
- Any backlogged issues from the previous day's LOTs are completed prior to issuing the new LOT 1 IPG IIs.
- SERVMART replenishments are a separate LOT and are issued after IPG II transactions have been processed.
- Discussions of LOTs and LOT sizes apply principally to the processing of binnable issues by AMHS. The estimated percentage of AMHS issues will be 65%; i.e., AMHS issues at the Broadway complex represent 65% of all NSC San Diego <u>non-Provisions</u> issues.

- AMHS accumulator line and packing line decisions implied or made by the lotting program are based on the number of requisitions per customer within each distinct IPG LOT.
- The LP and SP packing lines are generally used for large (greater than 124 line items) customers.
- The parcel post packing line is generally used for small (less than 5 line items) customers.
- The OP packing line is the "free flow" line along which all non-Bearer IPG I material is routed.
- The remaining ten packing lines receive material lotted for customers to whom greater than four but less than 125 line items are being issued. The ten AMHS accumulator lines, which are released one at a time, route material to the ten packing lines. A maximum of ten customers per accumulator line is permitted.
- A LOT is considered complete when the 10 accumulator lines plus the LP and SP lines are "filled" by the lotting program logic. Therefore, if the first LOT does not cover all the IPG II requisitions that must be issued, then the second LOT will also contain only IPG II issue documents. Similarly, two or three LOTs may be necessary to effect the issue and subsequent packing/consolidating of all IPG III transactions.
- Referencing a UIC locator/address file, the lotting program assigns a local delivery zone or indicates that shipping is required on the issue document.

- The lotting program attempts to equalize the workload represented by each accumulator line over the total number of LOTs each day.

No attempt will be made to duplicate the logic associated with the lotting program. The basic issue processing sequence described above will be followed, but no customer-related decision logic will be included in the model. The simulation of the packing function, which will be described in Chapter 9, will be greatly simplified based on the aforementioned equalized packing line workload characteristic of the lotting program.

A brief comment on Production Planning should be made before concluding the discussion of Figure 8-1. The model only recognizes the 24 hour Production Planning delay of selected IPG III issues. In actuality, the process is much more complex. Additional functions include the holding of issue documents for deployed ships and an effective backlog management routine that considers daily workload and local delivery schedules during the time-phased release of backlogged IPG III issues. This program, which was successfully operated in the past, has not been used recently due to a decreased operating tempo and other considerations.

B. DPD Q-GERT SYMBOLOGY

Figure 8-2 depicts the Q-GERT representation of the DPD demand processing, sorting, Production Planning, and lotting functions. Transactions to be processed arrive at Q-nodes 112 through 114 and regular node 115, which is in the routine batch processing stream that is initiated six times daily on Figure

6-5. As described below, each network category will be processed through the network logic on the upper portion of Figure 8-2 and, where appropriate, result in a demand exception, a referral, or occupancy in Q-node 126 for sorting and/or lotting on the midnight shift.

The contents of Q-node 6 on Figure 6-5 will be routed to regular node 115 via match node 10 six times each working day. The conditional branching at node 115 routes all non-SERVMART demands to node 119 for a demand exception check. The delay of 0.0001 hours on many of the Figure 8-2 branches is an arbitrarily chosen processing time that permits the handling of 10,000 transactions per hour, a figure that is well above the expected daily demand. Exceptions will occur at node 119 at the normal 6.2% rate and, since QUICK PIC does not arrive at node 119 through node 115, routine batch exceptions (A3.NE.3) will be routed from node 120 to Q-node 49 on Figure 7-5 for exception processing. If no exception is encountered, the standard gross availability check is made at node 127 with referrals being routed to node 65 on Figure 7-6 and potential issues to node 128. The conditional branching at node 128 functions to isolate IPG IIIs - SERVMARTs, Provisions, and In-Process IIIs are excluded - in order to assess the 24 hour Production Planning delay prior to their entry into the Sort/LOT queue. IPG II transactions are routed directly to Q-node 126 to await lotting in a "smallest value of attribute 3" priority. All transactions processed in DPD are eventually subjected to the Q-node 126 ranking procedure. Therefore, inasmuch

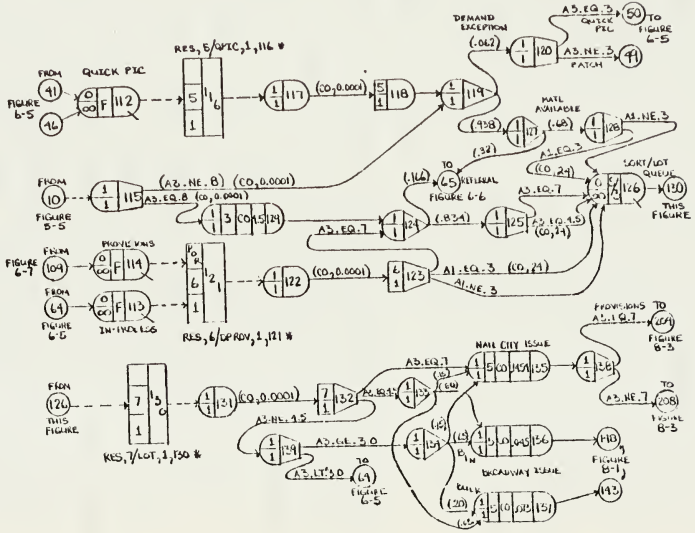


Figure 8-2. Data Processing Department

as IPH I requests (A3 = 1 or 2) will theoretically never be routed to this network segment, the first transactions in Q-node 126 at the time of lotting should be QUICK PIC demands.

The SERVMART transactions that were isolated at node 115 undergo a different processing procedure. First, their attribute 3 value is changed to 4.5 at node 129 to ensure positioning in Q-node 126 ahead of all other IPG III requests. Following the attribute reassignment, they are afforded an availability check equal to the NSC San Diego all cog net value of 83.4% and either routed to node 65 on Figure 7-6 for the collection of statistics on referrals or forwarded to node 125 where, once isolated again on the lower branch, they are routinely delayed for the standard 24 hours.

Having completed the discussion of the routing of routine batch input arriving via node 115, the QUICK PIC network segment beginning at Q-node 112 must be considered. Transactions shown arriving from nodes 41 and 46 on Figure 7-5 will not appear in Q-node 112 until after 1800 on each working day; the Customer Services QUICK PIC delay network precludes processing until that time. Since QUICK PIC requests are processed during a special 0100 run, no resources will be made available at allocate node 116 until that time. The initial allocation of 1 type 5 resource shown on the RES card above the allocate node was provided to comply with the Q-GERT requirement for an initial capacity greater than zero; this resource will immediately be removed in the Chapter 10 timing network and reapplied at 0100 on the appropriate days to accomplish the sequential

processing of QUICK PIC transactions in Q-node 112. The processing rate will be 10,000 per hour as shown on the branch between nodes 117 and 118, the free node. The QUICK PIC transactions are routed to the node 119 standard demand exception check and, provided an exception occurs, routed by the node 120 upper branch to the head of the queue at Q-node 50 on Figure 7-5 to ensure QUICK PIC exceptions receive expedited processing the next working day. If no exception occurs, QUICK PICs are routed through the same availability check and IPG III delay network-nodes 127 and 128 - that routine batch transactions encounter and theoretically become positioned at the head of Q-node 126.

The special Provisions run and the daily release of In-Process demands both occur at 1800. The network resource logic associated with Q-nodes 114 and 113 functions to arbitrarily give Provisions priority; Q-node 114 will be emptied before any transactions in Q-node 113 are processed. The resource scheme at allocate node 121 is similar to the QUICK PIC logic. The initial resource 6 capacity of 1 will immediately be altered to zero in the timing network. It will be reapplied at 1800 and transactions in Q-nodes 114 and 113 will be processed at a rate of 10,000 per hour. Both this resource and the QUICK PIC type 5 resource will remain available for a half hour. The Customer Services keypunch resource will be removed from 1800 to 1830 to prohibit the arrival of In-Process transactions during this admittedly extended period. This technique represents a more convenient modeling approach than a repetitive sampling

of Q-node contents from the timing network. The conditional branching at free node 123 routes Provisions documents to node 124 for a net availability check, delays the IPG III In-Process transactions 24 hours before entry to Q-node 126, and routes IPG II In-Process demands directly to the Sort/LOT queue for same night processing. Therefore, neither Provisions nor In-Process demands are given a demand exception check for reasons previously discussed. Furthermore, In-Process transactions are assumed to still be available and Provisions are considered available at the same net rate applied to SERVMART. This latter assumption could be made more realistic by using the availability rate for Provisions cogs only, but this degree of accuracy is not considered essential for this model. Provisions requests leaving node 124 are either referred through the branch to node 65 on Figure 7-6 or forwarded to node 125 where they are conditionally isolated and sent without delay to Q-node 126 to await lotting later that night.

The network segment beginning with allocate node 130 at the bottom of Figure 8-2 accomplishes as much of the actual lotting procedure as can conveniently be displayed in DPD. In particular, with the actual LOTs already determined by the ranking structure in Q-node 126, the sequential processing network beginning with node 130 serves solely to effect a warehouse distribution followed by the assignment of the appropriate issue time for that location. Since it's beyond the scope of this project to consider individual customer location (shipping or local delivery) and percentage of demand, numerous simplifying

assumptions regarding packing categories and shipping percentages will be made in Chapter 9. This procedure obviously deviates from the lotting explanation provided earlier in this chapter.

After initially being altered to zero, the single type 7 resource will be provided at allocate node 130 at 0300 and removed at 0500. Unless there are more than 20,000 transactions waiting in Q-node 126, which is highly unlikely, the two hours will be sufficient to empty the Sort/LOT queue. At free node 132 all Provisions requests are branched directly to node 135 for a National City issue time assignment to attribute 5, then sent to node 138 to be isolated once again and forwarded to a specific National City queue. All other National City issues arriving at node 138 are forwarded to a different queue to distinguish them from the Provisions demands in the issue processing priority scheme shown in Chapter 9. The middle branch from node 132 routes SERVMART requests to node 133 for the indicated probabilistic division into Broadway and National City issues, the assignment of appropriate issue times, and further routing as shown. The bottom branch from free node 132 to node 139, which routes all transactions other than SERVMART and Provisions, permits a "precautionary check" for IPG I transactions at node 139 prior to the indicated routing to node 134 for the standard non-Provisions issue branching of 65% Broadway bin, 20% Broadway bulk, and 15% National City that was first encountered on Figure 7-6. The bottom

branch from node 139 routes IPG Is that have inadvertently been subjected to DPD processing back to the IPG I processing stream on Figure 7-5. As a final comment, it should be noted that the Broadway bin issue time of 0.045 hours assigned at node 136 is significantly less than the 0.068 hours allotted to IPG Is at node 77 on Figure 7-6. The difference lies in the faster sequential processing of lotted bin issues using the AMHS capability in lieu of the IPG I unsequenced hotline issue procedure that acts as an interrupt to ongoing processing.

IX. ISSUE, PACKING, MARKING, AND LOCAL DELIVERY

A. DATA CONSIDERATIONS

The Broadway and National City issue, packing, and marking functions and the local delivery system are presented on Figures 9-1 through 9-4. Distinct network segments are provided for Broadway bin, Broadway bulk, and National City. The system displayed generally approximates operating procedures in effect in May 1980. However, procedural changes within the next few months are a virtual certainty. Therefore, the contemplated revisions are discussed in the last section of this chapter.

The processing times as well as the percentage estimates dictating the numerous probabilistic branches used in the model are of dubious validity. The DIMES issue times assigned to the transactions on Figure 8-2 were not disputed. However, both the Broadway and National City packing supervisors took exception to the packing standards established by the DIMES study and used in the reference (b) simulation. Therefore, revised standards based upon the supervisor's estimates were used fro packing and marking. Having observed the bulk packing operation, it appears much more realistic to use the updated version. The DIMES standard of 8.5 bulk light packs per hour is not nearly as realistic as the 2.15 line items/hour used to gauge the National City packers' performance. Marking times for bulk material going to shipping were also revised to reflect 10.5 line items per hour, or .095 hours per item, vice the

variable marking time scheme used in reference (b). Marking light and heavy packs is identical except for the size of the container being marked.

The difficulty in developing accurate branching percentage stems from the lack of line item work measurement statistics in the Material Department. Due to the degree of consolidation occurring in the packing process and the excessive bulk of much of the material that must be processed, the predominant work unit becomes measurement tons. Therefore, although information such as the number of measurement tons packed or sent to shipping is readily available, the percentage of line items receiving a particular kind of pack or requiring shipping remains a crude estimate at best. The same rationale applies to the distinction between light and heavy pack; the decision is based upon the volume of the container that must be processed. Neither line item volume nor a completely accurate representation of the impact of line item consolidation can be modeled. In fact, the effects of consolidation on bulk material are deliberately ignored during initial model formulation. Every bulk line item routed to packing at Broadway or National City is assigned a pack time. The rationale for this decision is presented during discussion of relevant Q-GERT network segments. Consolidation is a major factor in binnable item processing, however, and a detailed discussion of this concept is included in Section 9C.

Finally, the issue documents generated during the lotting process are picked up each morning and distributed to the

appropriate warehouse by the beginning of the day shift. The model does not simulate that messenger service. Transactions leaving DPD are routed directly to the appropriate issue queue. This technique introduces no error into the model. Although the transactions arrive at the Q-nodes prematurely, no resources are made available to process them until the day shift commences.

B. BROADWAY BULK MATERIAL PROCESSING

The complete Broadway bulk issue, packing, and marking process is displayed on Figure 9-1. The bulk input is shown arriving at Q-nodes 142 and 143 in the upper left portion of the figure. Q-node 142 contains only IPG I issue documents. Bearers arrive via node 97 from Figure 7-6 and, by virtue of an attribute 3 value of 1, assume a position at the head of the S/3 (smallest value of attribute 3) queue. The other IPG I issue documents, which are transported by messenger from node 92 on Figure 7-6, are routed to the queue from node 141. The conditional branching at that node separates the bulk issues from the bin issues that are carried to a different location by the same messenger. The 0.2 hour delay on the branch between nodes 141 and 142 is additive to the 0.4 hour document delay on Figure 7-6 and models the depositing of bin IPG I issue documents 0.2 of an hour before the bulk DD 1348-1s. The lotted output of Broadway bulk material, which contains only IPH II and III issues, is shown entering Q-node 143 from node 137 on Figure 8-2. Although a given day's lotting output will arrive at node 143 in IPG sequence, the F (First-In-First-Out)

ranking procedure will ensure that backlogged issues are processed before the higher priority transactions lotted the following day. Of course, IPG Is will always take precedence through being routed to the preferred queue, Q-node 142.

Nodes 144 though 146 represent the resource allocation network that performs the bulk issue. The RES card image above allocate node 144 indicates that 27 warehousemen are available each working day to make bulk issues. The RES card also indicates that this type 9 resource may only be allocated at node 144. The issue processing time, which was assigned as attribute 5 on Figures 7-6 and 8-2, is shown on the branch between node 145 and free node 146. Note that the free node has no allocate scheme beneath it. Therefore, the RES card order, node 144 only, prevails. In fact, throughout this chapter resources will generally be associated with a single allocate node and changes in capacity or the shifting of resources will have to be accomplished either through changes to the RES card(s) or alteration schemes similar to the issue/receipt example presented in Chapter 7. One type 9 resource will remain available for the second shift to ensure that IPG Is are processed. However, since the contents of Q-node 143 are also processed by the same resource, lower IPG backlog will also be issued and subsequently packed and/or marked during the evening shift. Similarly, an issue and packing resource will remain at Broadway bin and National City to guarantee that IPG Is are afforded the necessary expeditious treatment. The issue backlog processing feature <u>at all three</u>

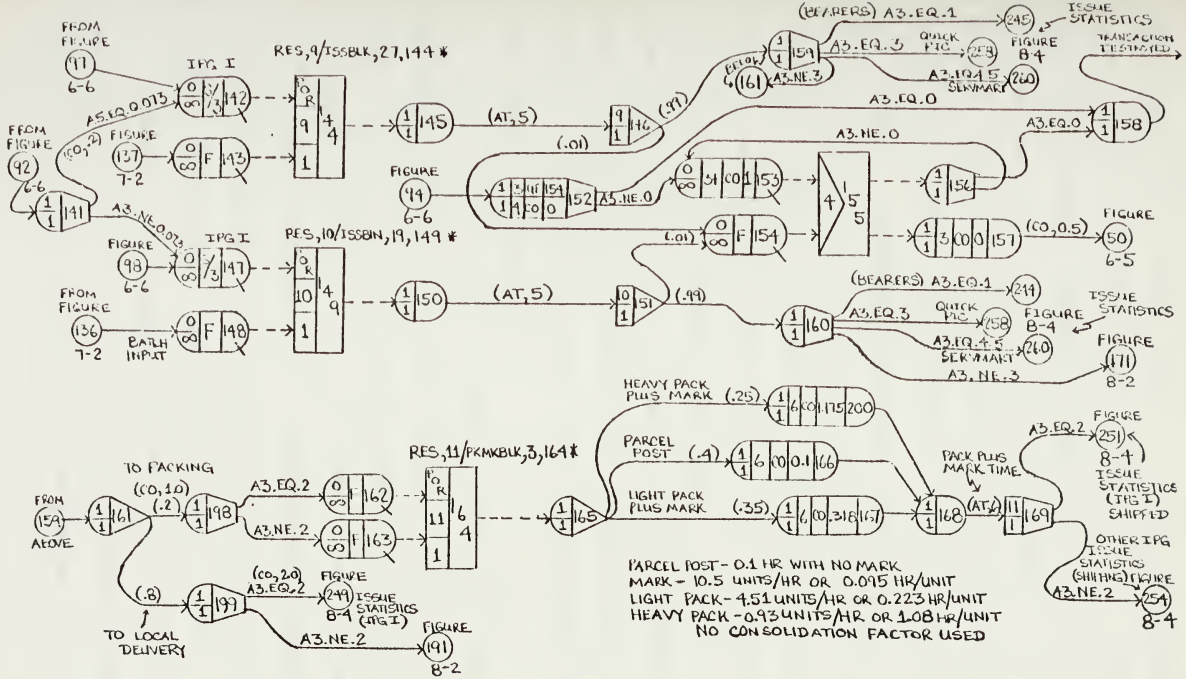


Figure 9-1. Broadway Issue and Bulk Pack/Mark

locations is not representative of actual operations. A Broadway issuer and packer are available for IPG I processing throughout the Broadway complex and backlog management as time permits. Modeling that procedure would require either distinct resource categorizations and allocate nodes for IPG I processors (see AMHS packing on Figure 9-2) or a separate evening shift model that would replace the existing network segments at 1600. Such complexity was not considered necessary. The network presented represents a satisfactory starting point. If initial runs yield a high percentage of idle resources, there are numerous alternatives that could be evaluated. For example, simulation time could be used to compute the shift on which an IPG I arrives and effect a routing to a special queue for second shift processing. This approach would be used in place of the retention of a second shift resource and eliminate the processing of lower priority backlog by focusing only on IPG Is after 1600.

After the resource is freed at node 146, the probabilistic branching designed to model warehouse refusals is encountered. The 1% branch leaving node 146 serves to route warehouse refusals to Q-node 154 where they await the arrival of the messenger from node 94 on Figure 7-6. The messenger network modeled by nodes 152 through 158 is basically identical to the similar segment described in detail in Chapter 5. The second input into Q-node 154 represents Broadway bin warehouse refusals. Although they are picked up at a different location, it is assumed that they accompany the messenger on the 0.2 hour

journey from the bin area to the bulk warehouse. Therefore, a single queue representation of warehouse refusal routing to Customer Services node 50 is realistic. Two differences from the Chapter 6 network segment are worthy of mention: (1) the warehouse refusals are assigned an attribute 3 value of 0 at node 157 to establish processing priorities on Figure 7-5; and (2) the messenger is not routed from node 158 since this network segment represents the last stop on his modeled run and each run is initiated from the timing network. Therefore, the messenger run time totals 1.9 hours consisting of 0.5 hours on Figure 6-5 (node 85), 0.8 hours on Figure 6-6 (node 87), and 0.6 hours on Figure 7-6 (node 94). The document delay of 0.4 hours leaving node 92 on Figure 7-6 represents travel time to the Broadway bin issue area. An additional 0.2 hours is assessed bulk issues on Figure 9-1.

The transactions routed along the upper branch leaving node 146 represent material issues. At node 159 Bearers are removed from the system as completed issues and routed to Figure 9-4 for issue statistics formulation; NSC San Diego has no further processing responsibility for Bearers once the material has been turned over to the representative of the requesting activity. However, bulk issues for both SERVMART and QUICK PIC transactions are also factored out as completed issues at node 159. QUICK PICs are isolated for transportation to the National City designated customer pick-up point. It was not considered necessary to model that segment of the QUICK PIC procedure. The statistics collected on Figure 9-4

are just as meaningful without the travel time to National City. SERVMART transactions are removed and sent to SERVMART Central Receiving where they undergo further processing to ensure compatability with the EPOS inventory system. The same procedure is followed for Broadway bin SERVMART issues. However, National City SERVMART issues, which constitute only 5% of the total, are staged in local delivery and transported to the appropriate zone as shown on Figure 9-3. The bottom branch leaving node 159 directs all other transactions to node 161 in the lower left portion of the figure.

The shipping/local delivery probabilistic branching occurs at node 161 with 80% of the transactions designated local delivery and routed to node 199 where IPG Is (non-Beareres) are terminated. Admittedly, indicating an issue completion at that juncture appears premature. However, local delivery IPG Is are not staged to await scheduled zone transportation; nor are they routed through any packing or marking evolutions. They are, however, considered individually and delivered by the most expedient available method. A more sophisticated study might consider the time of day and next scheduled delivery to the designated zone to facilitate the assignment of a more realistic issue completion time. However, meeting IPG I time frames has not been a problem at NSC San Diego. Therefore, only the standard two hour delay assigned as representative of the time between trips to local delivery staging has been acknowledged in the model. The similar delay for IPG II and

III local delivery material is shown on Figure 9-2 immediately preceding the bottom branch into node 191. The bypassing of packing and marking for local delivery bulk will apply to National City material as well. Only bulk material destined for shipping will undergo the packing evolution.

Broadway bulk material to be shipped represents 20% of the output from node 161. After being delayed one hour to roughly model transportation to the packing area, material to be packed arrives at node 198 where IPG Is are segregated and sent to Q-node 162 to ensure they receive preferred order processing by the resources allocated at node 164. Material that has been allotted type 11 resources is probabilistically routed to node 166 (40%), node 167 (35%), or node 200 (25%) for an attribute 6 assignment representing the indicated category of pack plus mark time. The type 11 resource capacity includes packers plus markers although the functions are generally performed independently with marking as a separate station following packing. However, since marking backlogs are a rarity, a first pass should be attempted with the functions combined. Since there is no mark standard associated with parcel post and light pack is marked approximately five times as fast as it's packed, a distinct marking resource would be idle over 95% of the time. A separate resource allocation network for the marking function can always be added between free node 169 - revised to provide a conditional branching that sends only light and heavy pack to marking - and the branching to issue statistics collection. The conditional branching from

node 169 on Figure 9-1 segregates IPG I material from all other categories and effectively completes the issue of packed and marked material sent to shipping. The packing and marking standards applicable to Broadway bulk are included on Figure 9-1 for ease of reference.

The branching from node 169 to the Figure 9-4 statistics collection network represents the completion of requisition processing by the model for items destined for shipping. However, the time being measured must not be interpreted as representative of the complete requisition processing sequence at NSC San Diego. Items exiting node 169 actually are staged for periodic delivery to shipping, which is located in National City. The subsequent events occurring in shipping constitute a requisition response time segment called Transportation Hold Time. This period, which includes functions such as selection of a shipping mode and consolidation of IPG III material for specific transportation categories, will not be modeled during this study. Therefore, the statistics collected for material sent to shipping are an estimate of the response time segment called Storage Site Processing Time. Of course, the model could be expanded to include the shipping function and transactions leaving node 169, and similar nodes on Figures 9-2 and 9-3, could be routed for additional processing. The model's treatment of local delivery material includes the Transportation Hold segment.

C. BROADWAY BIN MATERIAL PROCESSING

Bin material processing is illustrated on Figures 9-1 and 9-2. The routing through the bin issue process on Figure 9-1 is basically identical to the Broadway bulk issue process. IPG Is are routed to node 147 and all batch transactions are shown arriving from node 136 on Figure 8-2. The resource allocation network consisting of nodes 149 through 151 processes the contents of Q-node 147 (IPG Is) before transactions in node 148. The issue time is again the transaction attribute 5 value, which was assigned during the lotting procedure in Chapter 8 or on Figure 7-6 for IPG I requests. The FIFO ranking in Q-node 148 will ensure that backlog is processed before newly lotted transactions. Warehouse refusals are originated at free node 151 and routed to the messenger network described in the Broadway bulk discussion. Finally, QUICK PIC, SERVMART, and Bearer issues depart the system at node 160. The rationale for this decision was also presented in the discussion of bulk issues.

A few additional comments on the bin issue time are appropriate. First, IPG I issues, which represent an interrupt to sequential location processing, are assigned a larger issue time than lotted transactions. Secondly, the lotted line item issue time, while being lower than the IPG I value, includes an average UIC sort time. Lotted material is picked in location sequence then manually consolidated by UIC on a spar line before the tote pans holding the binnable material are forwarded

to packing via the AMHS accumulator lines. An awareness of this procedure is crucial to the discussion of the several posed procedural changes presented at the end of this section. Finally, consideration was given to assigning the higher IPG I issue time to QUICK PIC transactions. Their relatively low volume would appear to negate the benefits of the location sort they are given; i.e., there would still be a considerable distance between locations. However, since they are not subjected to the UIC sort that is included in the AMHS bin issue time, it was concluded that the faster time was more representative.

The remaining transactions departing node 160 are routed to node 171 on Figure 9-2 for IPG I segregation and application to the bin packing and marking network beginning with Q-nodes 172 and 179. At this juncture the current bin processing procedure differs from the bulk branching logic; all bin material, destined for both local delivery and shipping, goes through packing. Therefore, a probabilistic branch analagous to the node 161 (Figure 9-1) routing to local delivery is not required for bin material. All remaining IPG Is are branched to Q-node 172 on Figure 9-2 and all other transactions are routed to Q-node 179.

The Broadway bin packing and marking network contains two distinct resource types. The solitary type 12 resource allocated only at node 173 models the OP line along which all IPG Is are routed. This resource will remain available on the evening shift. However, since reallocation occurs only to node 173, the lower priority bin backlog in Q-node 179 will

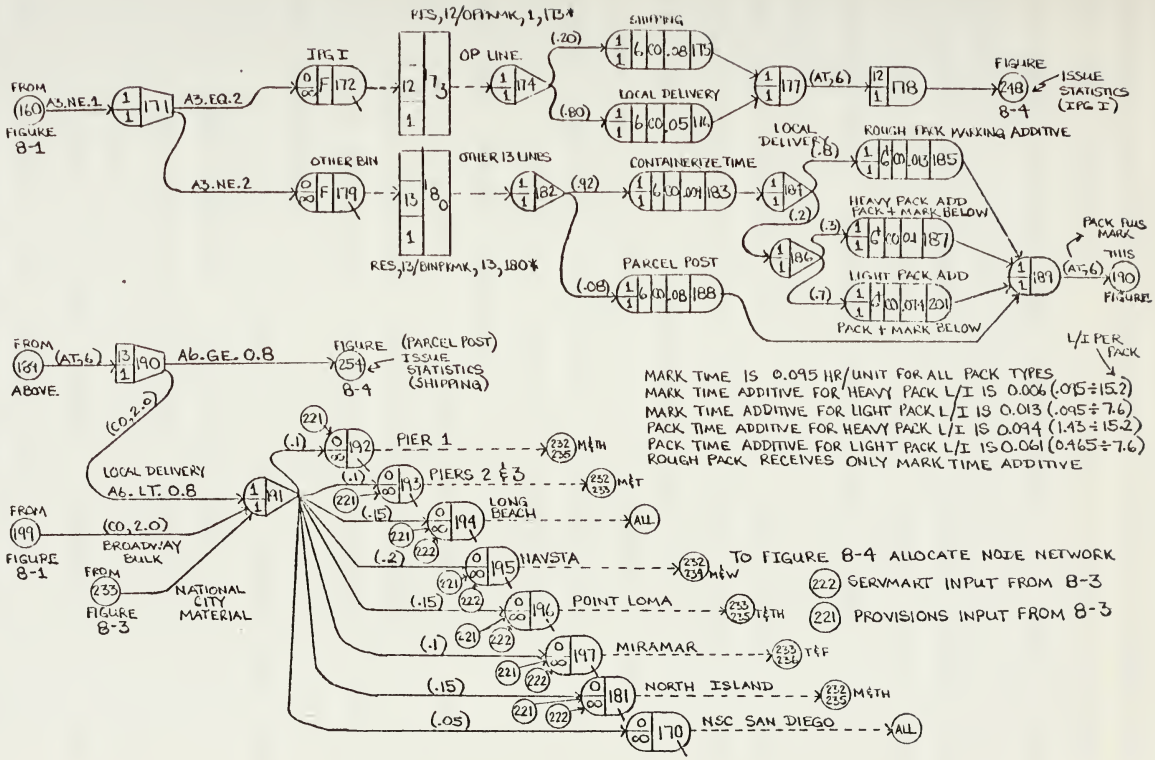


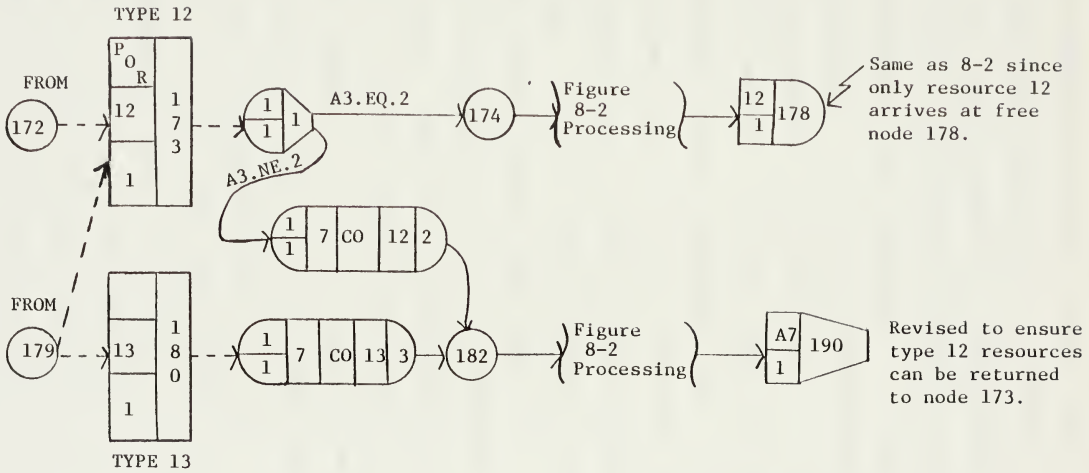
Figure 9-2. Broadway Bin Pack/Mark and Local Delivery Staging

not be packed and marked during the second shift. It was considered necessary to associate a distinct allocate node with IPG I transactions. Using the bulk packing procedure of a simple allocate node, 14 resources, and the IPG I queue designated as preferred would lead to situations where all 14 packers were processing IPG Is. Such an occurrence would be a complete distortion of reality; each of the 14 packers is assigned to a specific packing line and the lotting program attempts to equalize workload along 10 of these lines at least. The large customer lines, SP and LP, and the Parcel Post line receive material based on specific criteria that preclude workload equalization. Consideration was given to having the IPG I resource work secondarily on the contents of Q-node 179 in a manner similar to the Q-node 110 relationship to allocate node 103 on Figure 7-7 (envision a second dashed line originated at Q-node 179 and terminated at allocate node 173). This idea was discarded based on a reluctance to apply IPG I material for binnable items will theoretically be packed on a line item basis most of the time. Therefore, the packing times assigned should require little or no adjustment to incorporate the effects of packing numerous line items for the same customer in the same container. On the other hand, the material on every other line but Parcel Post is grouped by UIC and is afforded a packing standard that differs from the time associated with individual line item packing. Therefore, no attempt was made to model the IPG I packers involvement with material on other lines when Q-node 173 is empty. However, providing an

example of how such a procedure could be modeled will illustrate a useful method of using dissimilar resources to perform the same function.

The single digit numbers in the network above were added to the Figure 9-2 decision logic and free node 190 was modified to release either type 12 or 13 resources based on the attribute 7 value of the arriving transaction. All transactions arriving at node 3 from Q-node 179 will use type 13 resources. Therefore, an attribute 7 value of 13 is assigned to all transactions that are allocated resources by node 180. Allocate node 173, however, is modeled to enable processing of transactions from Q-node 179 must be subjected to the branching decisions beginning at node 182. Therefore, for an IPG II or III item, the lower branch is taken from node 1 and an attribute 7 value of 12 is assigned at node 2 before the transaction is processed at node 182 and beyond. Arrival of the transaction at free node 190 will then result in the correct type of resource being released. The objective of this example was to illustrate that free nodes need not be restrictive in the type of resources that they may release. It should be noted that free nodes such as 178 and 190 on Figure 9-2 will release <u>only</u> the designated type 12 and 13 resources, respectively.

Prior to completing the discussion of the Figure 9-2 network segment, the issue of consolidation and the rationale for the packing standards used for bin material must be addressed. The consolidation standard used in reference (b), which appears to have been applied to both bin and bulk items,


TYPE 12
P
O
R
FROM
172
12
1
1
7
3
1
1
1
A3.EQ.2
174
Figure
8-2
Processing
12
1
178
Same as 8-2 since only resource 12 arrives at free node 178.
A3.NE.2
1
1
7
CO
12
2
FROM
179
13
1
1
8
0
1
1
7
CO
13
3
182
Figure
8-2
Processing
A7
1
190
Revised to ensure type 12 resources can be returned to node 173.
TYPE 13

was 3.46 L/I (line items) per pack. This consolidation factor was used in conjunction with DIMES packing standards which, based on more recent observed production rates, appear to be too low. There is some bulk consolidation undertaken at National City, particularly with IPG III material. Nevertheless, a 3.46 L/I per pack average is considered too high to be representative of actual National City operations. A higher degree of consolidation is realized for Broadway bulk material and, consequently, the 3.46 average may be realistic. If initial simulation runs create excessive backlogs using the Figure 9-1 individual line item bulk packing procedure, then the consolidation feature can be modeled by creating a new mark plus pack time equal to the current value divided by the average number of line items per pack. It would appear prudent to initially simulate with a few values somewhat lower than 3.46.

The Broadway bin consolidation factor is assuredly higher than the 3.46 L/I value. Twelve of the fourteen packing lines theoretically receive material grouped by UIC with at least five line items per customer. It follows that the majority of the material on these 12 lines would be consolidated at a rate of at least five line items per pack. In fact, two of these twelve lines, LP and SP, will often contain over 200 line items for the same customer. Therefore, a consolidation factor limited only by the size of the container and/or subsequent transportation weight or volume constraints will apply. In view of the emphasis on consolidated packing of binnables, an admittedly rough approach for incorporating consolidation

into the initial model was developed and is presented during the discussion of the actual standards below.

The bin material packing categories may be summarized and modified in the following manner:

CATEGORY	PACK/HR	STANDARD HR/PACK	MODELED L/I PER PACK	STANDARS HR/LINE ITEM
Parcel Post	12.42/hr.	0.08	1	0.08
Rough Pack (Local Delivery)	14.59/hr.	0.068	7.6	0.009
Light Pack (Shipping)	2.15/hr.	0.465	7.6	0.07
Heavy Pack (Shipping)	0.7/hr.	1.43	15.2	0.103

Column three is simply the reciprocal of column two. It is displayed to provide a correlation with the processing time value assignments that are entered on the relevant network figures in terms of "standard" hours. The pack/hour standards were supplied by the NSC San Diego packing supervisors at Broadway and National City. Excluding IPG Is on the OP line and material on the parcel post line, all Broadway bin material can be viewed as receiving an initial rough pack consisting of the placing of all material for a particular UIC in a large container(s). Local delivery material would then receive negligible additional packing time and a relatively fast marking process. To the contrary, rough packed material destined for shipping would encounter significant additional packing time. The container would receive a light pack if its volume were less than 20 cubic feet or a heavy pack if larger.

The modeled L/I per pack values in column 4 were computed based upon the following assumptions: (1) the column two pack/hour is accurate; and (2) an arbitrary time of 0.5 minutes, or 0.009 standard hours as shown in the last column for rough pack, is needed to physically verify the UIC on a binnable item and place it in the appropriate container. Consequently, since it takes 0.068 hours to complete one rough pack, there are 7.6 L/I (0.068 ÷ 0.009) in each rough pack. The heavy pack modeled L/I per pack was arbitrarily set to twice the light pack value in recognition of the larger volume.

The standard hours/line item for material sent to shipping will be larger to reflect the actual packing evolution after the indicated number of line items are containerized. For the purposes of the initial runs of this model, the entire column three standard hour per pack value will be divided among the indicated number of line items per pack. Therefore, a light pack line item will be assessed an initial 0.009 hours plus its share of the 0.465 hours per light pack. The light pack hour per line item becomes 0.009 hours plus 0.465 ÷ 7.6 hours, or 0.009 plus .061, which is 0.07 hours. Based on the results of initial simulations, the modeler may wish to reduce the additional light pack assessment per line item to cover only the difference between the 0.465 hour per pack and the containerization time (0.009 × 7.6). Using this approach, 0.397 hours of light pack time, or 0.052 hours per line item, would be allocated across 7.6 line items. Then a total pack time of the standard 0.465 hours consisting of containerization

time (0.009×7.6) plus light pack time (0.052×7.6) would be realized. The technique currently used yields a total light pack time of 0.532 hours because the containerization time is additive to the total standard pack time.

The heavy pack time per line item is computed in a similar manner with the entire 1.43 hours per pack spread across the 15.2 line items per pack. Therefore, each line item will receive a 0.009 containerization time plus a 0.094 hour ($1.43 \div 15.2$) additive heavy pack time for a total of 0.103 hours. Once again the total heavy pack time will exceed the column three standard by the amount of time necessary to containerize the 15.2 line items.

The mark time standard of 10.5 packs per hour, or 0.095 hours, will also be distributed across the modeled line items per pack for items going to shipping.

Packing estimates in general, and this attempt to model the impact of binnable consolidation in particular, must be scrutinized, evaluated, and revised as needed. Although the rough pack standard is probably relatively accurate, the light and heavy pack estimates contain a significant amount of variability. Bulk packing estimates, which initially contain no consolidation feature, are exceptionally variable; the values specified represent an average of pack times that occasionally exceed eight hours.

To summarize, bulk material packing times are not adjusted for the impact of consolidation; items to be shipped are packed on a line item basis and local delivery bulk material bypasses

packing. Unrealistic bulk packing backlogs encountered in early simulation runs should first be addressed by incorporating a consolidation factor similar to the binnable approach. The binnable packing model, which is explained on a node-by-node basis below, represents the most reasonable initial approach available given the paucity of line item data. It should be emphasized that the accumulation technique described in Chapter 4 could be used to great advantage in any consolidation scheme <u>if</u> it were not necessary to maintain line item visibility. However, line item tracking is necessary for the computation of relevant processing statistics. The accumulation method is therefore unacceptable.

Returning to Figure 9-2, consider the network segment devoted to the packing and marking of the IPG I material residing in Q-node 172. When the solitary IPG packing resource becomes available, one IPG I binnable line item is released from Q-node 172 and subjected to the probabilistic branching at node 174. If the item must be shipped to a remote customer, the indicated 0.08 mark plus pack time is assigned to attribute 6 of the transaction at node 175. Although this value is equal to the binnable parcel post packing standard (which includes marking), it is not meant to indicate that all shipped IPG Is will be mailed. It is simply reasonable to assume that a line item of binnable material being prepared for shipment would be packaged in a manner similar to parcel post. It appears realistic to assume that line item quantities for IPG Is are not excessive and therefore are not subjected to a light pack rate

of 0.465 hours. Therefore, with the line item quantities small and consolidation ignored, a packing rate similar to parcel post seemed appropriate. Once again, if on-site evaluation indicates that IPG consolidation should be considered, the network segment should be modified. Although a batch input of IPG Is by a Fleet unit should be rare, it is probable that shore customers, particularly Naval Shipyard Long Beach, will occasionally originate multiple high priority requests.

The 80% of the IPG I local delivery material that is routed to node 176 is assigned a mark plus pack time of 0.05 hours. This value is arbitrary, but allowing three minutes to place a small item in a box or envelope and affixing the address portion of the DD 1348-1 seems adequate. Having assigned the appropriate pack plus mark time to attribute 6 of each IPG, the actual time is expended between nodes 177 and 178. The packing and marking completed, the resource is freed at node 178 and the issue is considered complete with the routing of the transaction to Figure 9-4 for the collection of statistics.

The processing of the lower priority material on the other 13 packing lines is somewhat more complex. First, parcel post line material, which is processed on a line item basis, is isolated and routed to node 188 by the probabilistic branching from node 182. The branch percentage value of 8% is slightly more than the percentage theoretically allotted to any one of the other 12 lines. This branching decision is once again simply a starting assumption and should be revised in the face of evidence to the contrary. As previously mentioned, lotted

material for small customers (less than five line items) is routed to the parcel post line without sorting. Therefore, each item will be processed separately and, despite the fact that a majority of the material on this line is slated for local delivery, each item will be assigned a parcel post pack plus mark time. This approach was adopted to model NSC San Diego's current procedure of mailing local delivery material to local Fleet customers. Using a special arrangement with both local and Naval Station postal authorities, this procedure generally leads to a one day delivery time, which represents an improvement over the delivery time normally attained through the use of the local delivery system. If this practice is discontinued, a regular node with probabilistic branching should be added prior to node 188 to provide routing to either a parcel post packing value assignment or a local delivery time standard with a lower value. Theoretically, the revision would yield a parcel post line network identical to nodes 174 through 176 of the IPG I processing segment.

Material branching from node 182 to the other 12 lines is immediately assigned an attribute 6 value of 0.009 hours at node 183 to represent the containerization function. Consolidation will occur whether the material is destined for shipping or local delivery. At node 184 the local delivery material is segregated and routed to node 185 where a marking time is added to the existing attribute 6 value. Therefore, local delivery material is not assigned any additional packing time beyond the 0.009 hours established at node 183. Since the mark time

standard of 0.095 hours applies to one container, the addition to each line item at node 185 is factored based on the 7.6 line items per rough pack assumption. Implicit in the treatment of local delivery material is the assumption that consolidation is occurring in light pack volume containers. If the local delivery material were divided into light and heavy rough pack through the inclusion of an additional probabilistic branch preceding node 185, the mark time additive for heavy rough pack would simply be reduced to half the light pack value since twice as many line items are in each heavy pack. Incidentally, assigning a full mark time to local delivery items is somewhat erroneous; the marking procedure is not as complex for local delivery containers.

The bottom branch from node 184 is taken by material destined for shipping. The 30% heavy pack branch from node 186 again has no statistical basis; it's simply a starting point. Parcel post, heavy, and light pack percentages for binnable material were not readily available. The attribute 6 additions at nodes 186 and 201 represent the pack plus mark value described below the nodes. The pack time addition was discussed earlier in this section.

The actual time to pack and mark is expended on the branch between nodes 189 and 190, the free node for this network segment. The conditional branching from the free node completes processing on parcel post items plus the material destined for shipping; the parcel post attribute 6 value will equal 0.08

and both light pack (0.083) and heavy pack (0.109) will exceed the node 190 upper branch lower bound.

Local delivery material, having an attribute 6 value of 0.022, will be routed along the lower branch from node 190, encounter the indicated two hour delay enroute to local delivery staging, and will be probabilistically assigned by node 191 to one of the eight indicated delivery zone queues. Local delivery will be discussed later in this chapter. It suffices to note at this point that these queues will be emptied in accordance with established delivery schedules. Broadway bulk material and National City local delivery material, less provisions and SERVMART, are also shown entering node 191. The direct input to selected zone Q-nodes consists of provisions and National City SERVMART material from Figure 9-3. Neither of these material categories go to all zones.

The issue process, and particularly the packing evolution, is a lucrative area for analysis through the use of alternative modeling schemes. All 13 lines could be modeled individually. More realistically, the large customer SP and LP lines might be modeled as a separate entity with two resources and a complete heavy pack operation in recognition of customer volume. The parcel post line is also a superb candidate for distinct resources. As noted in Chapter 8, the remaining 10 packing lines are basically indistinguishable due to the equalized workload principle. However, as the number of independent packing lines, and hence the number of distinct resource types, increases, provisions must be made for idle

resources to be allocated to busy lines; the packers do not remain idle if there's work to be done on other lines. The example shown earlier in the chapter that described the freeing of resources based on an attribute value set equal to the resource type could be used to eliminate any possibility of idle resources.

It should be apparent that the branching decisions and time assignments made throughout the issue, packing, and marking networks are crude at best. Knowledgeable NSC San Diego personnel should review and modify any noticeably inaccurate times or percentages as part of the pre-simulation validation process. If the final model is found to be useful for the purposes described in the introduction, It is imperative that sufficient data be collected to ultimately prescribe a model that approximates reality to the extent that it can confidently be used to assess the relative impact of various processing alternatives.

D. NATIONAL CITY MATERIAL PROCESSING

The National City operation depicted in Figure 9-3 is composed entirely of network structures that have been described in previous discussions. The resources allocated at nodes 203 and 210 process the contents of Q-nodes 202, 208, and 209 in the same manner as the DPD Keypunch queues on Figure 7-7. IPG Is in Q-node 202 are processed exclusively by the type 14 resources at allocate node 203. Similarly, Q-node 209 provisions documents are issued solely by the type 15 resource at allocate

node 210. The lotted Q-node 208 National City issue documents, which include QUICK PIC and SERVMART requests, may be processed by either type resource. It is anticipated that the lower volume in Q-node 202 will lead to the majority of the lotted material being issued by type 14 resources. Nevertheless, personnel devoted to provisions issues will issue lotted material from Q-node 208 when node 209 is empty.

Nodes 213 through 219 model the National City accumulation and forwarding of warehouse refusals originated at free nodes 205 and 212 of the issue processing networks. The messenger arriving at node 216 is the National City driver originally encountered on Figure 7-6. The operation of the network is identical to the warehouse refusal processing at Broadway described in conjunction with Figure 9-1.

Material issues take the 0.99 branches from free nodes 205 and 212. In the upper issue processing network, IPG I Bearers are immediately completed at node 206. QUICK PICs, which theoretically reside at the head of Q-node 208 at the beginning of each work day, are also extracted from the system at node 206; the only remaining action on these transactions is the delivery to the designated customer pick-up point. The FIFO queueing philosophy at node 208 ensures that lotted backlog is worked prior to beginning the issue of a new day's documents. Therefore, significant backlogs in Q-node 208 may prevent the expeditious processing of QUICK PIC issue documents and present a distorted picture of actual response time for this specific issue category. The standard Q-GERT analysis program output

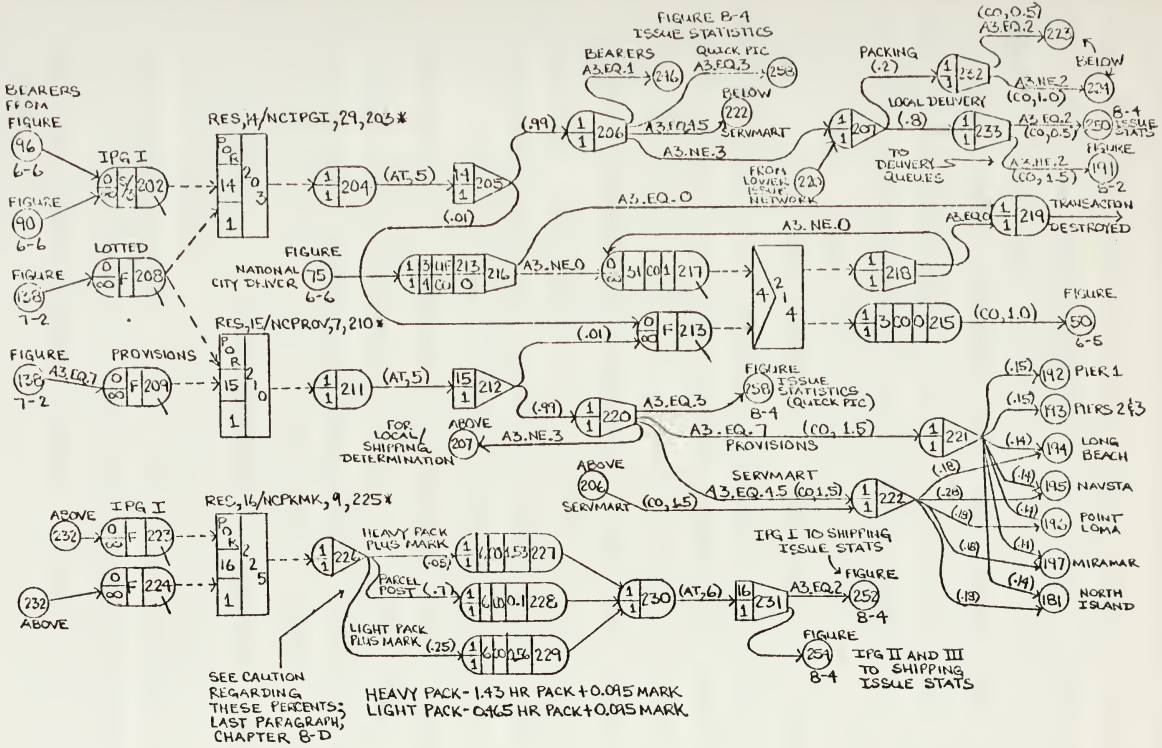


Figure 9-3. National City Issue and Pack/Mark

describing Q-node 208 should be closely reviewed in conjunction with the QUICK PIC output statistics collected on Figure 9-4. Bearing in mind that approximately a fifth of these transactions will routinely be delayed over the weekend, an unacceptably long QUICK PIC response time, which simply does not occur, may be countered through one of the following model revisions: (1) Isolate National City QUICK PIC documents with the addition of an A3.EQ.3 branch from node 138 on Figure 8-2 and route them to Q-node 202 on Figure 9-3 where they will be processed directly after IPG Is; or (2) perform the same isolation as above but route them to Provisions Q-node 209, which would have its ranking designator changed to S/3. A similar analysis should be conducted on Q-nodes 143 (bulk) and 148 (bin) on Figure 9-1. A remedial action similar to alternative (1) and featuring conditional branching of QUICK PICs directly from nodes 136 and 137 on Figure 8-2 to IPG I queues 147 and 142, respectively, on Figure 9-1 may be instituted if necessary. Although the routing of QUICK PICs to the IPG I queues may have been the most accurate modeling approach from the outset, the technique actually used was deliberately chosen to force an initial analysis of standard Q-GERT output for a specific material category. It was considered advantageous for the understanding of both Q-GERT symbology and standard program output to provide a specific analytical starting point for which the remedial modeling change, if needed, would be relatively minor.

Returning to Figure 9-3 at node 206, it should be noted that SERVMART transactions are routed to node 222 with a 1.5 hour delay for distribution to specific delivery zone queues. This procedure differs from the treatment given Broadway SERVMART material, which was considered complete with routing to SERVMART Central Receiving. There is no provisions (A3.EQ.7) branching from node 206 because the upper network does not process that material category.

The bottom branch from node 206 routes the remaining material to the local delivery or shipping/packing determination at node 207. Local delivery material is branched to node 233 where IPG Is are completed and the remaining material is delayed 1.5 hours enroute to the full range local delivery zone branching at node 191 on Figure 9-2. The conditional branching encountered at node 232 for items to be packed segregates the IPG I issues, delays them only 0.5 hours vice 1.0 hour for lower priorities, and designates the routing to Q-node 223, the IPG I packing queue. The remaining material to be packed is routed along the lower branch from node 232 to packing Q-node 224. Note that node 207 also makes the packing decision on material issued in the lower network segment; the lower branch from node 220 accomplishes the desired routing up to node 207.

The issue processing network using type 15 resources functions in a similar manner. However, provisions issues, which are made only by this resource, must be isolated and routed to the appropriate delivery zones. The segregation occurs at node

220 and the probabilistic branching to selected delivery zones is performed at node 221. The illustrated modeling scheme assumes all provisions requests are from local customers and the distribution of material issued is basically equal across all delivery zones. If these assumptions are erroneous, the appropriate network branching must be incorporated into the model and the corresponding Q-GERT cards changed accordingly.

Once material has been routed to Q-nodes 223 and 224, the packing queues, National City issues are packed and marked using network symbology identical to the Figure 9-1 Broadway bulk packing model. The mark standard of 0.095 hours and the parcel post 0.1 hour value are the same at both locations, but the light and heavy packing times at National City are higher. Note that there are three times more pack/mark resources at National City (9 type 16) than at Broadway (3 type 11). Inasmuch as there is a significantly larger percentage of light and heavy pack accomplished at Broadway, initial simulations may lead to both a large backlog in the Broadway packing queue, Q-node 163 on Figure 9-1, <u>and</u> a significant percentage of time idle for type 16 resources at National City. The higher percentages of light and heavy pack at Broadway more than compensate for the higher pack times at National City. Furthermore, the volume entering Broadway will theoretically be higher due to the exclusion of provisions from National City packing. The Broadway pack type percentages were supplied by the packing supervisor. The National City percentages were estimated based on the following data regarding pack type manpower assignments:

- 4 individuals are assigned to the light pack function which requires 0.465 hours per pack
- 2 individuals are assigned to the heavy pack function which requires 1.43 hours per pack
- 2 individuals are assigned to the parcel post function which requires 0.1 hours per pack

Assuming that the individuals assigned accomplish the required packing with negligible idleness and with minimal shifting of resources across functions, it was inferred that there is 14 times more parcel post business than heavy pack; the same number of people are kept busy performing a function that takes approximately 1/14 of the time needed for a heavy pack. Similarly, the ratio between parcel post and light pack personnel assigned and pack times implies that there is approximately 2.3 times more parcel post volume than light pack. Therefore, a ratio of 1:2.3:14 applies for parcel post, light, and heavy pack. The indicated percentages on the branches entering nodes 227 through 229 approximate that ratio, but are suspect in view of the corresponding Broadway bulk percentages. Therefore, standard Q-GERT output for Q-nodes 163 and 224 and the utilization of type 11 and 16 resources should be closely scrutinized. The resource levels and pack type percentages should also be reviewed on-site with appropriate packing supervisory personnel. If National City packing processes a significant input not included in this model, then the indicated resource capacity and/or pack percentages are invalid. Furthermore, if parcel post packers spend a significant part of their time

assisting in the light or heavy pack evolution, an adjustment corresponding to their degree of involvement must be made. Finally, the packing percentages are also based on the assumption that only one person is required to pack one line item, regardless of the pack type used. A determination that two people are used on each heavy and/or light pack would obviously alter these percentages.

E. LOCAL DELIVERY

The Q-GERT symbology modeling the local delivery system consists of the delivery zone queues on Figures 9-2 and the allocate node network, nodes 232 through 236, on Figure 9-4. The zone percentages emanating from node 191 on Figure 9-2 were supplied by Production Planning representatives. The zone percentages for National City provisions and SERVMART material given on Figure 9-3 and shown entering selected Figure 9-2 delivery zones from nodes 221 and 222 may be categorized as strictly arbitrary. Since only 5% of all SERVMART replenishments are issued from National City, revision of the branching proportions from node 222 should have little impact on the operation of the model. The provisions percentages should be reviewed, however. The equal branching assumption should be changed in the event that a higher percentage is routinely delivered to particular zones; e.g., if two large customers such as MCRD (Marine Corp Recruiting Depot) and NTC (Naval Training Center) occupy the same zone, the percentage assigned to that zone on Figure 9-3 should be adjusted accordingly.

The Figure 9-2 zone queues effectively model the staging of material for local customers by delivery zone. At the time of this writing, material was being staged strictly by UIC at the Broadway complex. Therefore, a significant manpower investment dedicated to locating all the material for a particular zone was required to determine the transportation resources needed to effect delivery the following day. The rationale for this seemingly inefficient staging method is unknown. The cost associated with converting to a UIC within delivery zone system apparently has either never been estimated or found to be prohibitive. If the former is the case, it would appear prudent to assess the costs and benefits associated with implementing a staging technique that would both simplify the determination of the transportation resource requirement and reduce the possibility of inadvertently overlooking small local customers spread throughout the staging area.

There is a local delivery staging area at both Broadway and National City. However, since material from each location is delivered on the same schedule to appropriate zones, the modeled approach consolidates them into one delivery system. The following nine zones, with their respective locations and delivery schedules given, comprise the NSC San Diego local delivery operation:

ZONE NUMBER	LOCATION	DELIVERY SCHEDULE
1	PIER 1	Monday and Thursday
2	PIER 2	Monday and Tuesday
3	PIER 3	Monday and Tuesday
4	LONG BEACH	Daily
5	NAVAL STATION	Monday and Wednesday
6	POINT LOMA	Tuesday and Thursday
7	NAS MIRAMAR	Tuesday and Friday
8	NAS NORTH ISLAND	Monday and Thursday
9	NSC SAN DIEGO (INTERNAL) AND TENANT ACTIVITIES	Daily

Although there are nine zones listed above, only eight zone queues appear on Figure 9-2. Piers 2 and 3, which share the same delivery schedule and the same transportation method (usually straddle truck), were combined into a single delivery zone. Pier 1 and NAS North Island, zones 1 and 8, also have a common delivery schedule, but require different transportation resources to physically move the material. Therefore, these zones were modeled as distinct despite their common schedule.

A change to the above zone definitions may have occurred before the distribution of this report. Material previously designated for zones 1 through 3 above will eventually be designated as Naval Station, zone 5, issues. Once implemented, this procedural change will restrict the zone designators

appearing on DD 1348-1 issue documents to 4 through 9. Piers 1, 2, and 3 are located at the Naval Station, a factor that tends to support a common zone designation. However, the delivery schedule for the four affected areas will purportedly remain the same. Therefore, the existing modeling approach will remain valid despite the revised zone designations. Of course, any change in delivery schedules would necessitate model revisions.

Numerous techniques could have been used to account for the Transportation Hold Time in local delivery. In fact, if each requisition's time in the system were the only factor of interest, there would be no need for either the Figure 9-2 Q-node network or the Figure 9-4 resources to process the Q-node contents. Following the zone determination at node 191, 221, or 222, each transaction could be assessed a delay determined by a distinct user function for each zone. The delay assigned would be computed as the difference between the next scheduled delivery day for that zone and the current day, which could be computed from simulation time through the use of modulo arithmetic. Having experienced the appropriate delay, each transaction would be routed to the statistics collection network. This technique was considered inadequate for the following reasons: (1) It does not provide illustrative Q-GERT graphics of local delivery, an exceptionally critical requisition processing functional area; (2) it does not represent a modeling approach that can readily be modified to incorporate either additional complexity or ensuing processing

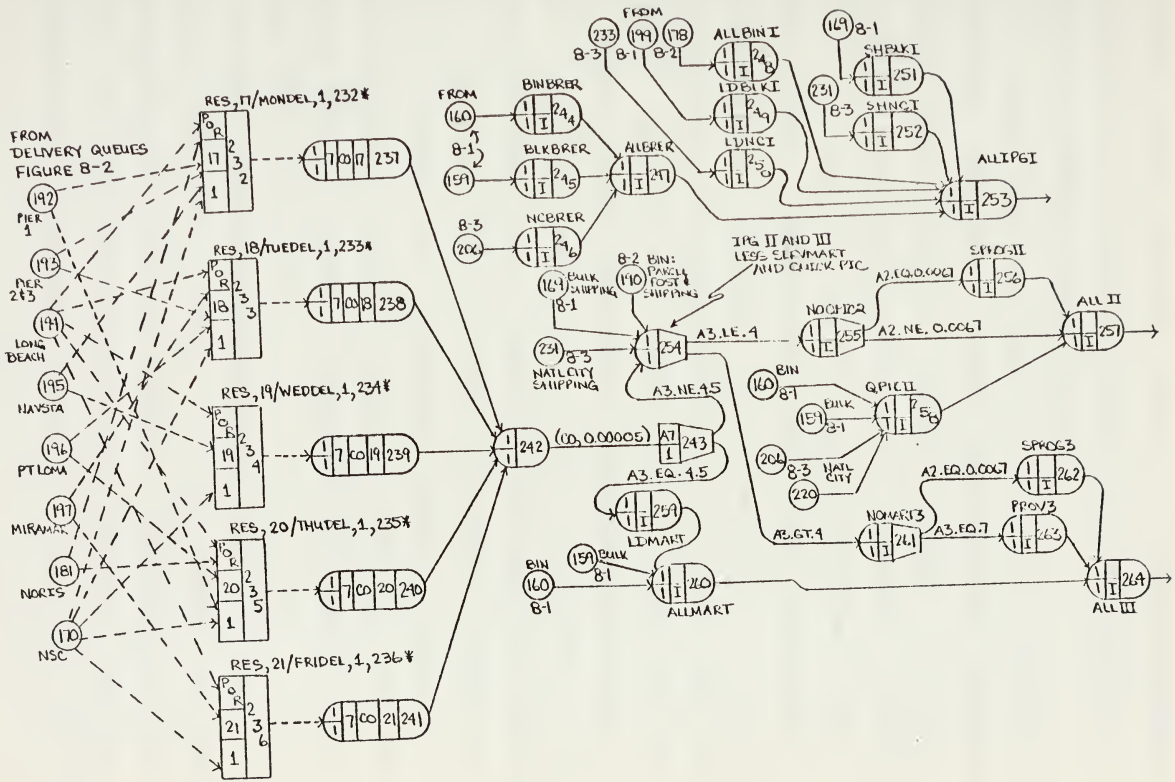


Figure 9-4. Local Delivery and Issue Statistics

functions; and (3) the FORTRAN background of the model's potential users may not be broad enough to include an exposure to concepts such as the modulo function. A stated objective of the model is to initially minimize both the quantity and complexity of FORTRAN program inserts.

The selected modeling scheme has none of the aforementioned objectionable features. It visually portrays each distinguishable zone's staging area as a Figure 9-2 Q-node. The dashed line leaving each Q-node terminates at a connector containing a list of the Figure 9-4 allocate nodes that process transactions residing in that queue. There is one allocate node for each weekday. Therefore, the ALL designator on the connectors for Q-nodes 194 (Long Beach) and 170 (NSC San Diego) indicates that resources are allocated for these queues each day; i.e., there are daily deliveries to Long Beach and NSC San Diego. Of course, the Figure 9-2 method of indicating routing to multiple nodes is not a standard Q-GERT graphical technique. Five dashed lines should have been originated at Q-nodes 194 and 170 and terminated at connectors labeled 232 through 236. Space constraints on Figure 9-2 prevented the use of the conventional graphical method. The appropriate standard routing is depicted on Figure 9-4.

The five dissimilar resource types at allocate nodes 232 through 236 are controlled from the timing network. The indicated capacity of 1 for each resource is immediately altered to zero. The positive integer initial capacity is necessary to avoid a fatal input error, which will inhibit the simulation

run. The immediate altering to zero prevents the processing of queued transactions until 1000 of the indicated weekday when one resource will be provided to empty all queues serviced by the available resource type. The logic associated with the local delivery network is basically identical to the ADP resource allocation symbology on Figure 8-2. The only notable difference is the frequency of resource availability; each ADP resource is provided daily for a specified time interval while delivery resources are made available once each week for a one hour period beginning at 1000. The 0.00005 hour local delivery processing rate, which is even faster than the ADP rate, was chosen to virtually guarantee that all the material in the given day's zones (Q-nodes) will be removed within the allotted hour. In addition, transactions arriving during the hour that resources are available will be processed if time permits. It appears reasonable to assume that material arriving prior to the completion of loading for delivery to a particular zone would be included in that day's delivery if adequate space is available.

The zone 4 Long Beach queue, which normally contains a large volume of higher priority material, will be designated the preferred queue at each allocate node. Q-node 170 material for NSC San Diego and its tenant activities, which is also delivered daily, will be coded as the least preferred queue. Special transportation resources are not generally provided for this material. Broadway material for this zone is already on-site. National City issues are normally included with the

shipment of Broadway material receipts that were inappropriately delivered to National City. Using the resource freeing techniques described in Section IX.D, nodes 237 through 241 assign the resource type as attribute 7 of each transaction routed through them. The resources may then be freed at the single network free node, node 243, and returned to the appropriate allocate node. Issues of local delivery material are considered complete after being removed from their respective Q-nodes and assessed the negligible 0.00005 hour delay. Therefore, the indicated conditional branching is taken from the local delivery network free node to the appropriate statistics collection network segments described in the next section.

The local delivery model selected assumes the availability of sufficient transportation resources to deliver all staged material. However, it could be easily modified to include an assessment of transportation requirements at the beginning of each work day by evaluating Q-node contents from the timing network. The same FORTRAN user function sown in Appendix D and used in the messenger routing system would apply. Based upon the queue contents, a specific number of the appropriate resource type could then be provided and a more realistic processing time assigned between nodes 242 and 243. In fact, the network could be retained in its present form with the exception of the free node 243 branching and used to provide the daily input to a transportation model. A given day's material for local delivery could be routed to free node 243 and deterministically branched to a Q-node that would serve as the input

queue for the transportation network. Decisions on required transportation resources, both personnel and vehicles, could then be made based on the contents of the added queue. Of course, the removal of material from local delivery staging should be accomplished earlier than 1000, perhaps the day before, and some provision to assess the impact of consolidation would have to be made; the zone queues contain line items rather than the actual consolidated material.

F. STATISTICS COLLECTION

The remainder of Figure 9-4 is devoted to the collection of issue statistics on various material categories. Each node with an I designation will automatically provide statistical output delineating time in system variables such as the average across all simulation runs, the standard deviation of this average, and the minimum and maximum times encountered. A histogram may also be provided by defining the first cell upper limit in Field 7 of the STAtistics node Q-GERT card. The card format permits labeling each STA node for ease of output identification. The label assigned to each node on Figure 9-4 is shown in the vicinity of the node.

Statistics nodes may be inserted throughout the network to collect data of interest. Since the STA node input card includes provisions for defining the histogram cell width, the number of transactions having a current time in system greater than some predetermined standard can be displayed in the last histogram cell. Furthermore, statistics on transaction time

in selected functional areas may readily be obtained through the use of mark nodes and STA nodes. The arrival time of the transaction assigned on Figure 6-5 or 6-6 need not accompany the requisition throughout the model. Including the M designator at any regular network node will result in a change of the mark time attribute to current simulation time. Therefore, if the collection of interval statistics on all transactions leaving Customer Services is followed by the assignment of a new mark time, the next interval data collected will measure the time following transaction departure from Customer Services. Of course, this technique would invalidate the use of the Figure 9-4 statistics as a measure of total processing time; the statistics collected would only measure the time between the last marking and issue completion.

A second method of conveniently determining average transaction time in a particular network segment involves the use of the multiple routing feature of deterministic branching. Assume that all transactions leaving a specified area are routed to a regular node with deterministic branching. Since a duplicate of each arriving transaction will be forwarded along every branch leaving the node, the requisitions can be routed on separate branches to both a statistics node and the next processing station without any mark time change. Each set of statistics collected in thismanner represents transaction time in the system at that point. Therefore, the time in a particular processing area may be computed, or at least inferred, from two successive sets of output statistics.

As previously mentioned, only the most rudimentary statistics collection features are programmed into the initial version of the model. The collection of data on the time between transactions was accomplished with referrals on Figure 7-6 and interval statistics are collected with the Figure 9-4 network logic. A practically unlimited degree of data collection sophistication may be included in subsequent versions through the use of FORTRAN inserts in conjunction with the guidance on user collected statistics provided in Chapter 9 of reference (a).

A node-by-node description of the Figure 9-4 issue statistics network will not be given. No additional Q-GERT concepts are introduced, the symbology used is relatively simple, and the material category for which the statistics are being collected is shown at the node.

G. POTENTIAL PROCEDURAL CHANGES

An evaluation of existing operational methods is constantly in process at NSC San Diego. In addition to the analysis of existing DPD procedures covered in Chapters 5 and 8, two procedural changes presently being contemplated in the material issue process are worthy of note at this juncture.

First, a change to the existing method of issuing and packing Broadway binnables is under consideration. The current procedure calls for all bin material to be routed through packing. The revised procedure would eliminate approximately 40% of the packing local delivery workload by accomplishing the

containerization of this material during the pre-packing UIC sort discussed in Section IX.C. The consequences of this particular type of revision could readily be evaluated using this model. A regular node with probabilistic branching could be inserted in the bottom branch leaving node 160 on Figure 9-1. This node would route 60% of all arriving transactions to node 171 on Figure 9-2 and redirect 40% to an alternate packing queue and network similar to nodes 179, 180, 183, 185, and 189 on Figure 9-2. A statistics node should also be added after node 189. Supplying one resource at the new packing station and simulating the revised model for a specified time period would permit an assessment of both production rate and backog at the additional station and the impact of the decreased workload on the current packing operation. Therefore, an estimate of the personnel reassignments needed, if any, to implement the procedure could be deduced from standard Q-GERT output for the relevant Q-nodes and statistics nodes. If the additional workload were to be assimilated by the issue resource, type 10 on Figure 9-1, the impact could be observed by slightly increasing the issue time on 40% of all binnable issues.

The second proposed change involves the application of the complete scope of Production Planning capabilities to the issuing of IPG III binnable material. The procedure, which was briefly discussed at the end of Chapter 8, involves a time phased release of IPG III material for local customers based upon the scheduled delivery date. The program objective was

to have the material arrive at the staging area during the afternoon preceding delivery. The new initiative goes one step further and includes the addition of a conveyor system upon which the material will be transported directly to waiting delivery vehicles. This procedure would obviously be more difficult to model. If the procedure is in effect when the second phase of this project begins, the necessary model revisions should definitely be made. A suggested starting point is the Figure 8-2 lotting logic; a zone determination could be made on local delivery material with probabilistic branching similar to node 191 on Figure 9-2. A variable delay could then be assessed for each transaction based on current simulation time and the next scheduled delivery. Of course, additional network logic would also have to be changed. The zone staging Q-nodes, for example, would simply not receive any IPG III material.

X. NETWORK TIMING

A. TIMING OVERVIEW

The network timing logic is used to initiate messenger runs, apply and remove ADP, local delivery, and personnel resources, and change the autodin and POE arrival patterns on a daily basis. Numerous modeling approaches could be used to provide the exact timing scheme developed in this chapter. The most efficient method would place a heavy reliance on FORTRAN program inserts. The seclected method was chosen for both its simplicity and the ease with which it may be modified and/or expanded to provide weekend or midnight shift resources.

There are two basic approaches that may be used to model the standard five day work week. If the functions occurring each day are identical, the most convenient technique involves the modeling of one day's events and a decision network that provides five repetitions of the same sequence of events before initiating a weekend delay. If the daily events differ significantly, it becomes less confusing if a representation of the entire week is modeled and relevant functions are initiated from each specific day. Of course, the former approach uses significantly less nodes and represents the ideal technique for any approach that is heavily dependent on FORTRAN inserts. For example, as each repetition of the standard day's network is initiated, a user function could be called to determine

which day of the week was commencing and what events must be scheduled. Mindful of the objective to minimize program inserts in the initial model, the timing network contains no FORTRAN logic. A disjoint network for the entire week is provided. However, in an attempt to illustrate both of the aforementioned techniques, the initiation of the entire week's schedule of selected events occurs on Monday rather than on a daily basis.

B. WEEKLY MASTER AND RESOURCE INITIALIZATION

The upper portion of Figure 10-1 contains a source node, node 265, and a closed loop of nodes and delays that total 168 hours or one week. The model itself, and each successive week, starts on Monday at 0430, the time indicated on both sides of node 266. The time was indicated twice as a reminder that transaction time through a regular node is zerop i.e., there is no delay at a regular node that requires only one transaction to release it. The 0430 start time was chosen to correspond to the changing of the autodin daily demand distribution. Since autodin referral input usually originates at east coast ICPs, it appeared reasonable to program the demand pattern change at the beginning of the ICP working day.

Two regular nodes representing 0430 and 1530 are encountered for each day of the week. The routing from nodes 266 and 267 occurs on Monday and the 61 hour delay initiated on Friday at 1530 from node 275 is the weekend delay. Obviously, a Saturday shift could easily be added by inserting regular

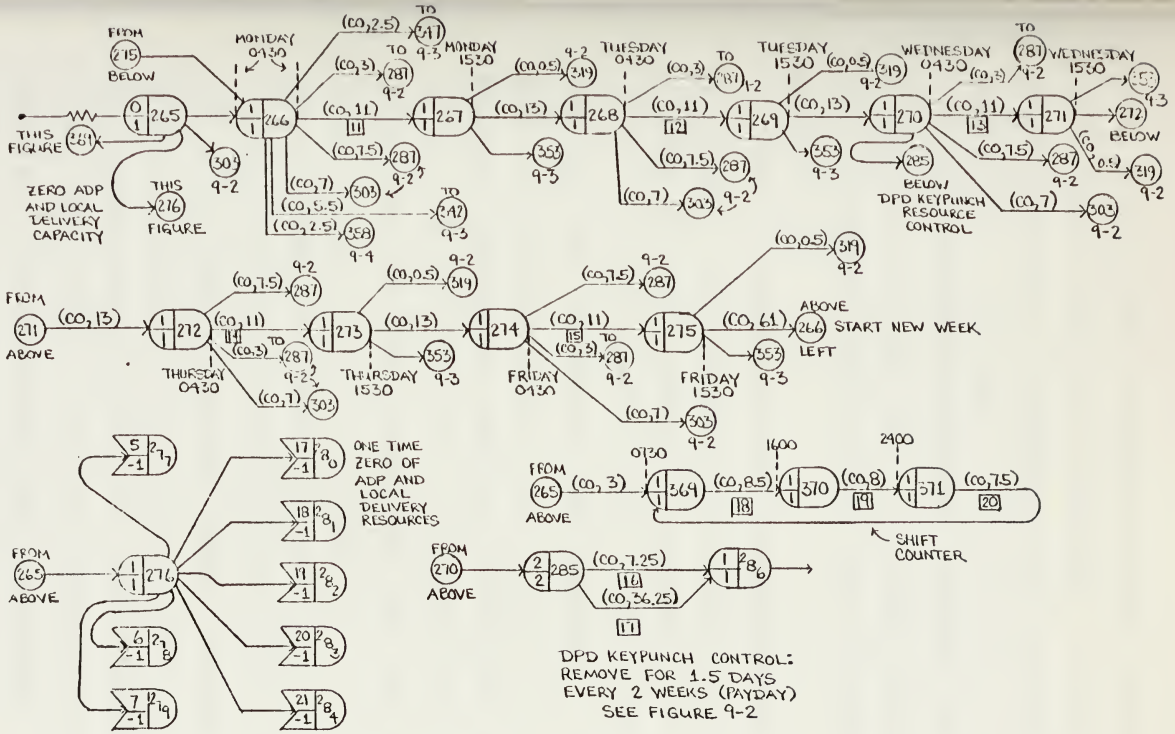


Figure 10-1. Weekly Master, Initialization, and DPD Keypunch Control

nodes after node 275 to represent specific times and decreasing the indicated 61 hour delay accordingly. The 1530 time designation was chosen to correspond to the termination of the daily eight hour POE input. Since POE input is terminated by a nodal modification procedure triggered by the completion of specific activities, the 11 hour delays preceding each 1530 node are assigned activity numbers that are referenced on Figure 10-4.

Each 0430 node routes two transactions to node 287 on Figure 10-2, the personnel resource control network. The transaction with the three hour delay arrives at node 287 at 0730 and sets all personnel resource types to the capacity indicated above the allocate nodes displayed in earlier chapters. The other transaction sent to node 287 is delayed 7.5 hours and restores the resources at 1200 after their removal for a 0.5 hour lunch at 1130. The removal of all resources, which is also initiated at each 0430 node, is accomplished by the routing to node 303 on Figure 10-2. The seven hour delay programs the transaction's arrival at 1130.

The routing of two transactions to node 287 and one to node 303 is common to each 0430 node in the week. However, Monday's node has three additional branches that initiate network segments that provide a full week's scheduling. The transaction arriving at node 347 on Figure 10-3 after a 2.5 hour delay initiates the <u>day shift activities</u> of the Broadway Complex messenger and the National City driver. The transaction routed to node 342 on Figure 10-3 initiates local delivery

resource control for the week. Finally, the routing to Figure 10-4, node 358, leads to the control of a full week's batch processing, QUICK PIC keypunching, and ADP resource allocation.

Node 270, the Wednesday 0430 node, has one unique branch to node 285 to provide specific resource control for DPD keypunch personnel, resource types 3 and 4 on Figure 7-7. This special network segment, which is shown on the bottom, middle portion of Figure 10-1, serves to eliminate these resources for a 1.5 day period every two weeks to model payday impact. A transaction is sent from node 270 to node 285 at 0430 each Wednesday. However, node 285 will not be released until two transactions have arrived. Therefore, every other Wednesday node 285 is released and activities 16 and 17, representing delays of 7.25 and 36.25 hours, respectively, are initiated. Activity 16 will be completed at 1145 on Wednesday, a time during which all resources have been removed for lunch. The completion of this activity prompts the modification of nodes 288, 304, and 320 on Figure 10-2 and inhibits any resource changes until activity 17, the 36.25 hour delay completes and reinserts those nodes in the network. The completion of activity 17 occurs at 1615 on Thursday or 15 minutes after the normal removal of DPD keypunch resources on each working day. Therefore, DPD keypunch resources, having been removed for Wednesday afternoon and Thursday, will be provided once again at 0730 on Friday.

Each 1530 node in the weekly master network has the same two branches. First, a transaction is delayed 0.5 hours and sent to node 319 on Figure 10-2 to initiate the 1600 shift/ resource change. Finally, a transaction is sent to node 353 on Figure 10-3 to trigger the network that provides second shift messenger service for both the Broadway Complex and National City.

To conclude the discussion of Figure 10-1, the branching from node 265, a source node, to nodes 303 and 276 must be considered. The routing without delay to node 303 on Figure 10-2, which is normally accessed to remove all personnel resources for the lunch break, is a one time initialization of all personnel resources to zero. If this step were omitted, the transaction arriving at node 287 at 0730 from node 266 would result in twice the defined capacity of each personnel resource being available. The RES card for each resource contained a capacity field and, in the absence of an altering action, that capacity is assumed to exist when the simulation commences. Therefore, the altering of resources up to capacity that is initiated at node 287 would actually double all resources that were not initially zeroed.

The transaction routed from node 265 to node 276 also provides an intialization function. It was mentioned in Chapters 7 and 9 that the ideal initial capacity for ADP and local delivery resources would be zero, an assignment that was prohibited due to the requirement for a positive integer capacity. Therefore, these particular resources were defined with a RES

card capacity of one, which would immediately be reduced to the desired zero value and made available when required. The network consisting of nodes 276 through 284 simply accomplishes the desired reduction to zero for both ADP resources at nodes 277 through 279 and local delivery daily resources at nodes 280 through 284.

The final branch emanating from the source node triggers the disjoint timing network beginning with node 369, which is above the Figure 10-1 DPD keypunch control segment. Once initiated, this segment runs continuously. The completion of each activity signifies the end of a shift. Activity 18, which completes at 1600, represents the end of the first shift. Activities 19 and 20 are completed at 2400 and 0730, respectively, and model the end of second and third shifts. The completion of activities 18 and 19 controls the Figure 7-5 nodal modification between nodes 48 and 51. Since this simple timing network runs continuously, the modification will also occur on Saturday and Sunday. With no weekend shifts in this version of the model, the Saturday and Sunday node replacements neither serve any specific purpose nor introduce any erroneous transaction processing. Therefore, it was not considered necessary to create a weekend delay simply to inhibit that modification. Subsequent modelers should be aware that the modification is occurring each day and, if necessary, revise the network segment to inhibit or provide a revised modification procedure. For example, the Customer Services Saturday and Sunday shifts are basically identical to the weekday second

shift. Therefore, the indicated modeler action would consist of retaining node 51 for the entire weekend.

It should be apparent that the weekly master could easily be replaced by a relatively simple daily master. The unique networks accessed from node 266 would have to be restructured to represent a single day's processing instead of a full week and the payday resource impact could be incorporated without any FORTRAN program inserts. However, the weekly master is considered an excellent starting point for providing a more realistic visual display of daily events and for acquiring a more thorough understanding of the network segments through repetitive referral to the same functional areas. In addition, the approach used greatly simplifies the addition of any daily uniques or changes in a specific day's event scheduling the user may wish to model and evaluate.

C. PERSONNEL RESOURCE CONTROL

There are 21 distinct resource types defined in the model and 13 of them are personnel resources that must be provided and removed in accordance with established working schedules. It is recognized that some of these resources, although modeled as unique, are actually interchangeable. Nevertheless, the initial model does not provide the capability for dissimilar resources to process the same transaction types. Earlier chapters did, however, provide examples of modeling approaches that could be used to effect such a processing technique. When the model is validated and operating satisfactorily, embellishments

can be added to model such procedures as a routine day's end backlog evaluation leading to resource shifts and/or the addition of a complete shift.

Figure 10-2 is conceptually very uncomplicated despite its excessive number of nodes. Each column of alter nodes contains one node for each of the 13 personnel resource types. The leftmost column of alter nodes is activated twice each day from the 0430 nodes (266 is Monday, 268 is Tuesday, etc.) on Figure 10-1 to reinstate the entire capacity of each resource at 0730 and 1200. The lower left partition represents the capacity change made to the resource type shown in the partition above it. Consequently, it is apparent that the middle column of alter nodes, which prompt a capacity change that is the negative of the left column, functions to zero all resources. This action is originated once only from source node 265 then once each day at 1130 from the same Figure 10-1 nodes that trigger the full capacity increases at nodes 290 through 302.

The first two alter nodes in each column are the DPD keypunch resources, types 3 and 4, which are removed from the network when activity 16 has been completed and caused the replacement of nodes 288, 304, and 320 by nodes 289, 305, and 321, respectively. When node 289 is in the network, there is no further routing of transactions arriving at node 288; the transactions are subjected to the routing emanating from the node that is presently in the circuit and, since node 289 provides no further routing, the transaction is destroyed. It

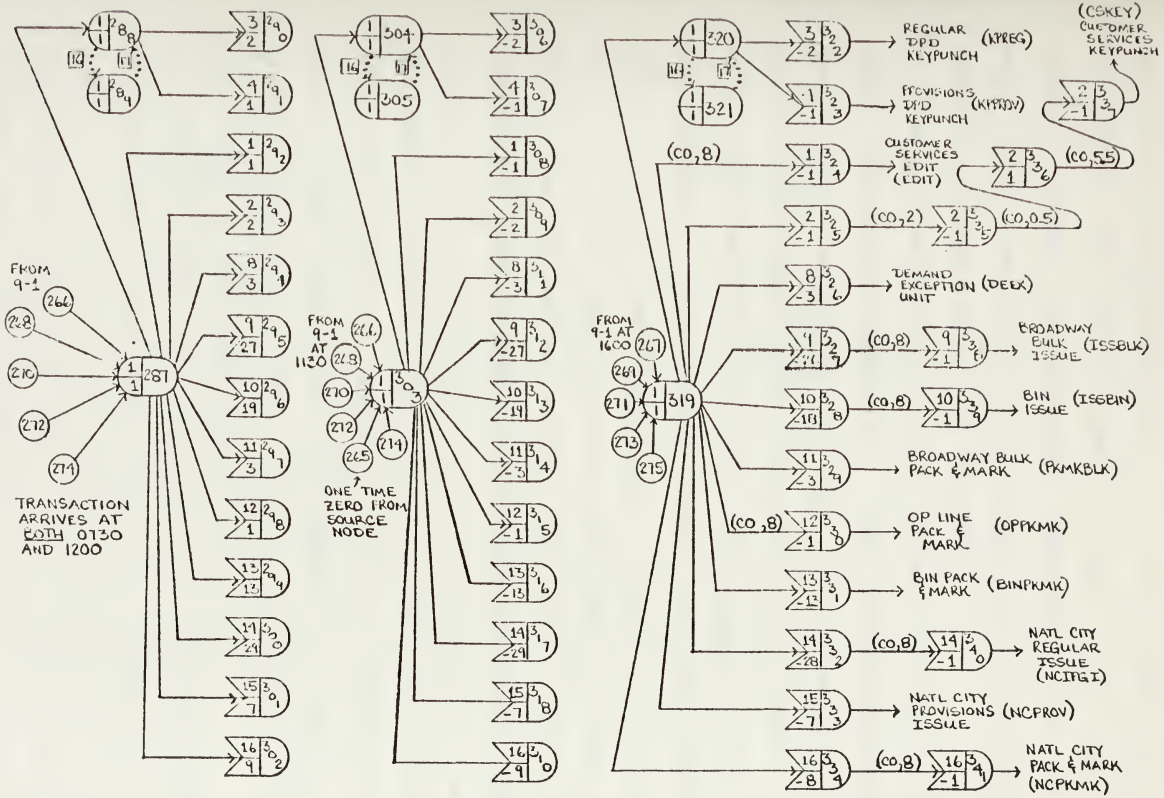


Figure 10-2. Personnel Resource Control

should be noted that both 304 and 320 could have also been replaced by node 289 if conserving nodes were an overriding factor. In fact, one node could have been used for the entire model to receive all transactions and replace all nodes for which no further routing was desired.

The rightmost column of alter nodes is activated from each day's 1530 node on Figure 10-1. This network segment provides second shift resource control andprovides a description of each resource type for the convenience of the reader. Resource types encountering no delay at any point after node 319 are reduced to a zero capacity at 1600 and remain unaltered until 0730 on the next working day. Therefore, resource types 3, 4, 8, 11, 13, and 15 have no second shift personnel assigned. This can be verified by comparing the 1600 resource changes in these nodes with the middle column resource zeroing capacity changes; they are identical so no resources remain after 1600. The lack of a second shift type 11 resource will prohibit the packing and marking of Broadway bulk IPG Is destined for shipping until the next working day. This approach was deliberate to prompt a comparison of IPG I statistics collected on Figure 9-4. This factor is mentioned again in Chapter 11.

Resource types 1 and 12 encounter an eight hour delay before arriving at alter nodes 324 and 330, respectively. Therefore, the reduction to zero occurs at 2400 and indicates the second shift capacity is equal to the day shift capacity of one Customer Services edit resource and one IPG I (OP line) packer/marker.

Rsources types 9, 10, 14, and 16 undergo a 1600 alteration that leaves one of each resource available until the midnight zeroing action at nodes 338, 339, 340, and 341.

Resource type 2, Customer Services keypunch, is reduced to one at 1600 at node 325. However, since the entry of transactions in-process is to be inhibited during the release of demands in-process from 1800 to 1830, this second shift resource is removed during that period by alter node 335 and reinstated at 1830 by alter node 336. This resource is also zeroed at 2400 at node 337.

Note that different second shift resource schemes, or even the addition of a midnight shift, can easily be incorporated into the Figure 10-2 logic. A complete third shift could be modeled through the addition of a new alter node column with capacity increases equal to the desired number of each resource type. The capacity cahnge could be initiated after an 8.5 hour delay from the Figure 10-1 daily 1530 nodes.

D. LOCAL DELIVERY AND MESSENGER SCHEDULING

Figure 10-3 contains three distinct network segments referenced in the discussion of the weekly master on Figure 10-1. The upper two segments are each initiated by the arrival of a single transaction from node 266, the Monday 0430 node, and the lower segment is activated daily from the 1530 nodes.

The lower network is the second shift messenger control logic. It activates two messenger runs per shift to both Broadway and National City. For example, a transaction arrives

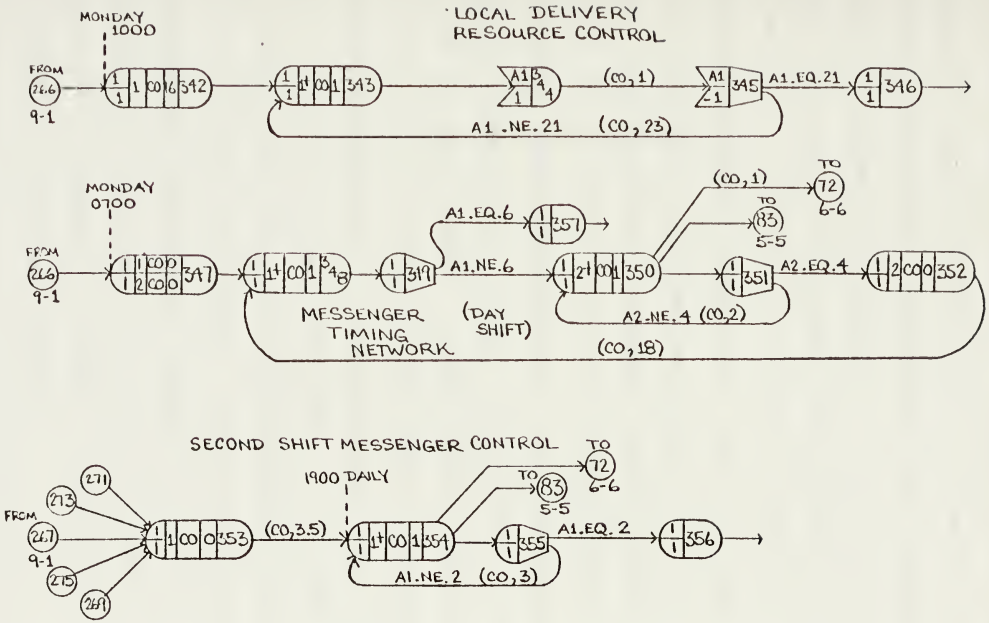


Figure 10-3. Local Delivery and Messenger Control

at node 353 from node 267 on Monday at 1530. Attribute 1 of the transaction is set to zero and a 3.5 hour delay is initiated when node 353 is released. The transaction arrives at node 354 at 1900 where a constant 1 is added to the attribute 1 value and transactions are routed to nodes 83 and 72 to initiate Broadway and National City messenger runs, respectively. The complete Broadway run consuming 1.9 hours will be made. Future model revisions could provide a more realistic approach by concentrating only on the transfer of autodin IPG Is to Customer Services (Q-node 5 on Figure 5-5) and IPG I issue documents to the appropriate Broadway warehouse area (Q-note 78 on Figure 7-6). The second shift messenger timing was modeled independent of the day shift runs to facilitate future revisions. Eliminating selected segments of the complete messenger run sequence represents a greater challenge than it would appear to pose at first glance. A user function that determines selected queue contents and then sends an identical number of matching transactions to the appropriate match node represents one of the more logical approaches. If, in fact, the contents of Q-node 25 are routinely taken to DPD on the second shift, then no revision is necessary. This situation should be researched when the model is reviewed with NSC San Diego personnel. The National City logic associated with node 72 does not provide a run if Q-node 70 is empty. Therefore, no modification of that logic should be required.

Returning to Figure 10-3, the initiation of the 1900 runs is followed by the conditional branching evaluation at node 355.

Since attribute 1 is one at 1900, the lower branch back to node 354, which contains a three hour delay, will be taken. The transaction attribute 1 value will be increased to two at 2200 and a second messenger run will begin. At this time the upper branch from node 355 will be taken and no further routing will be provided from node 356.

The network in themiddle of Figure 10-3 models the day shift messenger service for the entire week. A transaction that has been delayed for 2.5 hours arrives at node 347 at 0700 each Monday. Both attribute 1, which is incremented with each day change, and attribute 2, which is incremented with each of the four daily runs, are initially set to zero. At node 348, the day of the week is increased by one and an immediate check is made at node 349 to determine whether it is the sixth day. If it is, the transaction is sent to node 357 and routed no further; a run with attribute 1 set at six would represent a Saturday run, which is not included in this version of the model. Note that node 349 is actually extraneous. The conditional branches could have been evaluated directly from node 348 since attribute assignments are made prior to evaluating branching conditions.

If attribute 1 is one through five, the transaction is routed to node 350 where the attribute 2 value is increased by one at the same time runs are initiated by the transactions routed to nodes 72 and 83. Therefore, the fourth and final daily run will be initiated at the same time the attribute 2 value becomes four. There are no delays encountered between

node 347 and the arrival of the first transaction at node 83. Therefore, the first Broadway messenger run occurs at 0700. Due to the one hour delay on the branch from node 350 to 72, the first National City run occurs at 0800.

After a run is initiated from node 350, attribute 4 is evaluated at node 351. This node is not extraneous; deterministic branching was mandatory at node 350 for messenger run initiation. If attribute 4 is not equal to four, the lower branch is taken from node 351 and the incrementing of attribute 2 plus another messenger run is accomplished two hours later. The last of the four daily runs begins at the same time attribute 2 is increased to four, which occurs at 1300 and leads to the transaction taking the upper branch from node 351 to 352. The process must begin again at 0700 the next working day. Therefore, attribute 2 is reset to zero at node 352 and an 18 hour delay is initiated to time the transaction's 0700 arrival at node 348.

The network initiates four messenger runs for each attribute 1 value from one to five. This provides 20 runs a week. It should be apparent that a similar technique would be used to model five repetitions of a daily master if that approach had been used in place of the Figure 10-1 weekly network.

The upper network on Figure 10-3 functions to provide the appropriate local delivery resource (type 17 on Monday, 18 on Tuesday, etc.) for one hour commencing at 1000 on the appropriate day. In this case, however, the resource type is the value

that is initialized, incremented each 24 hours, and evaluated to determine the end of the week.

The transaction arriving at node 342 from Figure 10-1 at 1000 on each Monday is assigned an attribute 1 value of 16, which is immediately incremented to 17 at node 343. The type resource provided by node 344 and retained for one hour before being removed at node 345 is determined by the attribute 1 value of the arriving transaction. Therefore, a type 17 resource will be provided at 1000 on Monday, removed at 1100 by alter node 345, and routed along the lower conditional branch where a 23 hour delay will be initiated. Each transaction taking the lower branch from node 345 will arrive at node 343 at 1000 the following day and have its attribute 1 value increased to equal the required local delivery resource type for that day. Since the resource type has been available for the specified one hour period when the node 345 branching evaluation occurs, an attribute 1 value of 21, the Friday local delivery resource type, indicates that the week's local delivery routine has been completed. Therefore, when attribute 1 is equal to 21, the transaction is routed to node 346 and no further.

E. ADP RESOURCE CONTROL AND BATCH PROCESSING

The upper portion of Figure 10-4, which is also activated once each week from node 266 on Figure 10-1, initiates six batch processing runs each work day and also provides ADP resource control for the entire week.

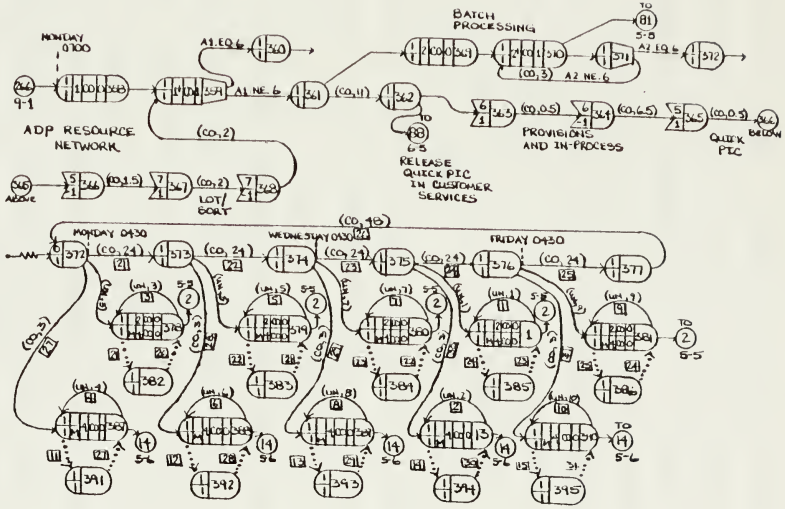


Figure 10-4. ADP Resource and Demand Pattern Control

The modeling technique is similar to a combination of the two upper network segments on Figure 10-3. The initial attribute 1 assignment of zero at node 358 is immediately incremented by one at node 359 where the end-of-week test is made. Since attribute 1 is equal to one at the first node 359 branching evaluation, the transaction will be routed to node 361 for the indicated parallel branching to node 369 for batch processing and to node 362 for both ADP resource control and the release of QUICK PIC transactions waiting in Q-node 37 on Figure 7-5. Node 369 of the batch processing network initializes the run count, attribute 2, to zero at 0700 and routes the transaction to node 370 where the count is immediately incremented by one and the 0700 batch run is initiated through the routing to node 81 on Figure 6-5. The lower branch from node 371, with its accompanying three hour delay, will be taken until the sixth batch run, which occurs at 2200, is initiated. Attribute 2 will equal six at that time, the upper branch from node 371 will be taken, and no further batch runs will occur until the next transaction is routed to node 369 from node 361; i.e., at 0700 on the next working day.

The 11 hour delay on the lower deterministic branch from node 361 models the 1800 arrival of the transaction at node 362. The routing to node 88 on Figure 7-5 triggers the release of QUICK PIC transactions in node 37 to either DPD (mechanized) or Customer Services keypunch. Since there's no time expended between nodes 362 and 363, a type 6 resource is also provided at 1800 by alter node 363. It should be clear

that node 362 is not actually needed; the routing to node 88 could have been provided with an additional branch from node 363. The type 6 resource, the ADP resource that releases in-process transactions and accomplishes the 1800 special provisions run, remains available for 0.5 hours until removed at node 364. The 6.5 hour delay after node 364 models the elapsed time before the application of type 5 resources at 0100 to provide demand processing of QUICK PIC requisitions waiting in Q-node 112 on Figure 8-2. The type 5 resource is removed one-half hour later at 0130. Nodes 367 and 368 provide the type 5 lotting resources for the two hour period between 0300 and 0500. The two hour delay after node 368 completes the 24 hour period between arrivals at node 359.

Therefore, the network logic beginning at node 361 will provide five successive days of the aforementioned processing sequence for each transaction arriving at node 358 from Figure 7-1. As shown on Figure 10-4, the processing period commences at 0700 on each Monday and terminates at 0700 on the following Saturday. This approach is not completely accurate. Some of the late Friday and early Saturday processing is actually conducted late Sunday and early Monday. For example, an 0100 QUICK PIC run is conducted early on Monday rather than early on Saturday. Since the basic model has no weekend shift, the total delay is not changed. QUICK PIC transactions simply spend the weekend in an issue queue instead of DPD Q-node 112. However, if issue resources were made available on Saturday, a model revision would be needed to either delay the QUICK PIC

issues until Monday or reschedule their demand processing and sorting for early Monday. A thorough review of current NSC San Diego ADP scheduling should be undertakn during the model validation phase. A Saturday warehouse work force appears imminent and is probably already operational. If all or most of the issues lotted early Saturday are issued over the weekend, the inclusion of weekend autodin arrivals, which actually do occur, limited weekend batch runs, and an 0300 Monday lotting jrogram may also be advisable (along with the aforementioned change to the QUICK PIC processing schedule). One of the more convenient features of modeling with a weekly master is the ease with which events unqiue to a specific day may be added, deleted, or otherwise modified and subsequently displayed with representative new or altered network symbology.

F. AUTODIN AND POE ARRIVAL PATTERNS

There are a wide variety of modeling techniques that could be used to change the daily demand interarrival pattern for both autodin and POE input. The autodin interarrival pattern created at node 1 on Figure 6-5 is from the uniform distribution described in parameter set 1. The parameters for this distribution were developed in Chapter 5 and represent the Thursday autodin uniform interarrival pattern. Similarly, the Figure 6-6 node 13 POE interarrival process, which is described in parameter set 2, represents an eight hour Thursday demand pattern. The parameter set values corresponding to this distribution were also computed in Chapter 5.

A distinct parameter set must be used to describe each day's autodin and POE interarrival process. In retrospect, it is unfortunate that parameter set 1 and activity number 1 were associated with Thursday's demand data. It would have been more convenient to have parameter sets 1 through 5 correspond to autodin interarrivals for Monday through Friday, respectively. POE interarrivals could then have been described in parameter sets 6 through 10. Completed figures were not changed simply to provide more conventional numbering schemes. Future modelers, however, would be well advised to adopt a more logical numbering pattern to avoid any possible confusion.

The network symbology in the bottom half of Figure 10-4 replaces the Figures 6-5 and 6-6 segments preceding nodes 2 and 14, respectively. The Appendix E program listing groups all Q-GERT cards pertaining to a particular figure together. The cards corresponding to the Figure 10-4 sequential delay network, nodes 372 through 377 and all branches leaving these nodes, are included with the coding for Figure 6-5. The nodal modification network containing "create" nodes 378 through 380 plus 1 and 381 represent the daily autodin arrival patterns and are therefore also listed with the Figure 6-5 cards. The lower create node network, which includes node 13 from Figure 6-6, switches the POE interarrival distribution daily and is therefore listed with the POE categorization cards from Figure 6-6.

The term create node refers to a node that functions to generate transactions until some programmed event such as nodal

modification occurs to terminate the cycle. By routing a duplicate of each transaction back through an interarrival delay to serve as the next input, nodes such as 378 will generate transactions indefinitely unless inhibited in some manner. The replacement (modification) of node 378 by node 382 when activity 21 has completed terminates the regenerative process.

Node 372 is a source node and will be released when the simulation begins. Unlike source node 265 on Figure 10-1, which routes multiple transactions one time and then becomes inactive, node 372 is part of the sequential delay network containing nodes 373 through 377 and is released each Monday at 0430. Therefore, the 24 hour delays designated activities 21 through 25 are completed at 0430 Tuesday through 0430 Saturday, respectively. Activity 26, the 48 hour delay between nodes 377 and 372, models the weekend period during which no demands are generated.

Nodes 372 through 376 each route the three following transactions each time they are released: (1) the activation of a 24 hour delay; (2) the activation of an interarrival delay which, when completed, will trigger 24 consecutive hours of autodin input; and (3) the activation of a three hour delay before initiating the appropriate day's POE arrivals, which will terminate after eight hours.

There are significant differences between the autodin and POE switching networks. For comparison purposes, consider the routing from node 373, which occurs at 0430 each Tuesday.

Activity 22, the 24 hour delay commences. When this activity completes, the Tuesday autodin arrival process generated by node 379 must be terminated. The activity 22 indicator beside the dotted line pointing at node 383 implies that node 383 replaces node 379 when activity 22 is completed. Therefore, create node 379 is deactivated at 0430 on Wednesday. Note that node 379 will reenter the network (replace 383) when activity 21 has been completed. There can be no doubt that activity 21 will complete before the initiating transaction arrives at node 379. First, activity 21, which is the delay preceding node 373, will be completed at precisley 0430 on Tuesday while the arrival of a transaction at create node 379 from node 373 will be further delayed by an amount equal to a sample from the uniform distribution described in parameter set 5. Secondly, even if there were no uniform delay between nodes 373 and 379, the very existence of node 373 in the network would ensure that activity 21 completed and node 379 subsequently reentered the network before a transaction was routed from node 373 to 379; although no simulation time is expended traversing node 373, the Q-GERT scheduling process recognizes transaction arrival at a node and makes all necessary network adjustments, including modifications, before routing the transaction elsewhere. Thus, even without the uniform delay, create node 379 would be in the network when the initiating transaction arrived from node 373.

The preceding points, which may appear to have been belabored, were provided to simplify the discussion of the contrasts in

the switching network for POE arrivals. The branch from node 373 to node 388, Tuesday's POE create node, contains a three hour delay to inhibit the activation of POE arrivals until 0730. In this case, the completion of activity 28 results in the simultaneous arrival of a transaction at node 388 and entry of that same node as the replacement for node 392. The question of which event, transaction arrival or the modification, occurs first is obviously relevant. If the arrival occurred without the modification, then node 392 would receive the transaction and route it no further. Therefore, no POE arrivals would be generated. A call to Pritsker and Associates yielded an assurance that the modification will occur first. However, if simulation statistics indicate no POE input is being generated, then the problem can be resolved by inserting a regular node in the network after the three hour delay and before node 388. A parameter set 6 uniform delay need not be included between the new node and node 388, but it is more accurate to have one. The transaction arriving at the create node not only starts the arrival process, but also represents the day's first arrival. Therefore, the first daily autodin arrival is always delayed by an amount determined by the appropriate uniform parameter set. The first POE arrival, on the other hand, always occurs at 0730.

The discussion of the Tuesday network segment applies to every other day, also. It should be apparent that a Saturday and/or Sunday arrival process may readily be inserted by splitting the 48 hour delay at activity 26 and adding autodin and/or POE

network setments similar to the daily symbology shown on Figure 10-4.

As a final comment on Figure 10-4, activities 11 through 15, which function to terminate the daily POE arrivals, are each 11 hour delays from the Figure 10-1 weekly master. The activity completion time is 1530 in each case with activity 11 representing Monday, activity 12 Tuesday, and so forth. Once again, each create node could have been replaced by the same inhibiting/terminating node. Distinct nodes to inhibit the interarrival process were used solely for graphic clarity.

The number of alternatives to the selected modeling approach are practically unbounded. The Figure 10-4 model, which can be easily modified due to being nearly completely disjoint from other network segments, was chosen as an alternate to the replacement of one create node by another through a process called serial nodal modifications. The autodin and POE arrival processes could have been modeled in a fashion similar to the Figure 10-5 examples shown below. The create node numbers are identical to the Figure 10-4 node numbers, but the mark function and attribute assignments are omitted and no further routing is shown.

The network segment presented in Figure 10-5 is provided for illustrative purposes only. The interarrival parameter sets are not shown and the midweek segment of the POE network was omitted because it was simply a repetition of the preceding nodes. The intent here is to comment on the serial nodal

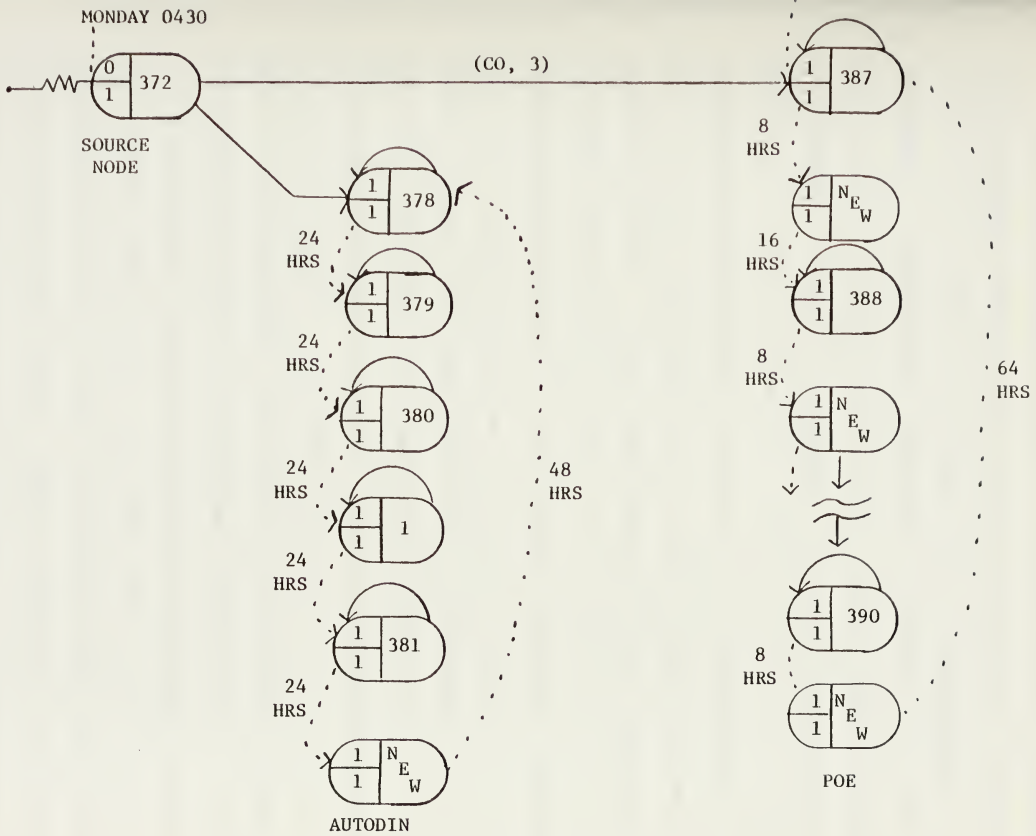


Figure 10-5. Serial Nodal Modification

modification process, not to provide an operational alternative to Figure 10-4.

The autodin network shown on the left side of Figure 10-5 would probably function for one week if node 372, the source, node, were not adapted to trigger node 378 each week at 0430 on Monday. Consider the replacement of node 378 by 379. When the 24 hour delay that brings node 379 into the network is complete, there will probably still be an interarrival delay in process at node 378. If this is the case, the delayed transaction arriving at node 378 will be transferred to node 379, which has replaced node 378, and initiate the next day's arrival pattern. If the modification and the completion of the node 378 interarrival delay occur simultaneously, there is no assurance node 379 will ever be triggered. Therefore, specific triggers should be provided for each autodin create node at 0430 on the appropriate day to guarantee its activation. Once the NEW regular node has replaced node 381 at 0430 on Saturday, no further arrivals will be generated unless another trigger is routed to node 378. Node 378 will replace the NEW node at 0430 on Monday, but will not be activated unless triggered from node 372 or from some other network segment.

Using similar logic, an external trigger must be provided at each POE create node. Each NEW node's time in the network represents the 1530 to 0730 (or weekend) delay during which no POE requisitions arrive. When a NEW node is replaced by a create node such as node 388, there is no possibility of any interarrivals in process serving to activate the create

node just added. Therefore, the POE switching network shown would generate arrivals for the first Monday only if no subsequent transactions arrived from node 372 or every Monday if there were a weekly trigger from node 372 or elsewhere.

The create node activation problem is surmountable. The approach was avoided due to a lack of understanding of the description given serial modification on pages 178 and 179 of reference (a). This text was exceptionally thorough in most cases. The examples are excellent and the concepts were generally presented very clearly. However, more specifics regarding the effects of nodal modification, both serial and simple replacement, would have been helpful. In addition, an expanded explanation or definition of the "node released" and "activity completed" criteria may have eliminated some confusion. The status of a node, released or not released, can be used as a branching condition; it is somewhat unclear whether a node released once can ever again assume a not released status. A similar vagueness surrounds the concept of a completed activity; for example, is an activity that is not in process categorized as completed? This question is particularly relevant in nodal modification modeling.

The most efficient approach to modeling the switching or interarrival patterns would rely on FORTRAN program inserts. The create node interarrival distribution could be defined as a user function, UF, which could be programmed to compute the day of the week from simulation time, variable TNOW, and select an interarrival time using the parameter set applicable to that

day. Therefore, only one autodin and one POE create node would be needed. This approach is made possible by the accessibility of the parameter set matrix through FORTRAN program inserts. In accordance with the objective of minimizing FORTRAN coding, the less efficient but more illustrative approach was taken once again.

XI. SUMMARY AND CONCLUSIONS

A. MODEL VALIDATION

This section actually deals with the two distinct processes of verification and validation. Verification of the model consists solely of ensuring that it is operational; no consideration is given to how realistically it portrays the system being modeled. The next few paragraphs cite various segments and aspects of the model that should be carefully reviewed during the verification process.

The messenger service described in great detail during the discussion of Figure 6-5 should be closely scrutinized. This process was developed to overcome the absence of a standard Q-GERT capability to release all queued transactions simultaneously. Adding a branch from node 84 on Figure 6-5 to a statistics node collecting "between" data should indicate whether the modeled technique is functioning properly; the time between arrivals at node 84 should be zero during the queue emptying process and the first cell of the statistics node histogram can be defined with a zero upper limit. The output "between" statistics should then reveal a preponderance of zeroes plus values greater than or equal to two, the minimum time between messenger runs (day shift).

If the technique does not work, the batch node networks can be replaced by a resource allocation scheme that may either be similar to the ADP processing technique (capacity of

1 with an extremely fast processing time) or provide a resource capacity equal to the number of transactions waiting to be removed. In the latter case, the Appendix D User Function could be modified to alter resources after determining queue contents. Neither modification may ever be necessary; Pritsker and Associates is currently testing a technique to effect the simultaneous movement of all transactions in a Q-node and, if successful, Q-GERT may have a messenger capability by the time the model is verified.

A caution was provided regarding the concurrent insertion of the Figure 10-4 POE create nodes and the arrival of the initiating, and only, transaction at that same node. Therefore, this network segment must also be carefully reviewed during verification and, if necessary, the compensating revisions specified in Chapter 10 should be accomplished.

The COMMON statement in the Appendix D User Function will have to be changed to provide the necessary dimensioning for the 1,000 node model. The appropriate COMMON block will be apparent when the 1,000 node version is installed. If it is needed any earlier, Pritsker and Associates can provide it.

SERVMART transactions were originally assigned an attribute 3 value of 8 on Figure 6-6. This value was then changed to 4.5 on Figure 8-2 to ensure SERVMART replenishments were lotted first among IPG III requisitions. Although the system will operate satisfactorily with this reassignment, it is unnecessary and subsequent modelers may wish to simply assign an original

attribute 3 value of 4.5 to SERVMARTs on Figure 6-6 and delete the Figure 8-2 value assignment.

Before preceding to the model validation discussion, a peculiarity in the use of Q-GERT resources must be mentioned. The initial queue capacity of a resource al-ocation network Q-node must be zero. Therefore, a simulation can not be commenced with a representative backlog loaded in Q-nodes that are serviced by network resources. However, since the time to begin statistics collection is defined on input (on the GEN card), the modeler can and should delay the start of statistics collection until a time period sufficient to stabilize the system has passed.

The model's validity is determined by the extent to which it duplicates the system or situation it was created to represent. Validating the model is the process of comparing model output with observed system data and resolving the discrepancies. The following paragraphs contain information that is relevant to the validation process. Most of these topics were emphasized as potential problem areas in Chapters 5 through 9 and are reiterated solely for the convenience of the reader.

The development of the 6.2% demand exception rate, the lack of confidence in its accuracy, and the difficulties associated with determining a better estimate were covered in Chapter 5. It should prove beneficial to deveease this rate in selected simulations and note the impact on the average number of transactions in the Customer Services keypunch and edit queues on Figure 7-5. Obviously, any research leading

to a more accurate estimate of this rate would contribute to the model's validity.

The demand data in Appendix B was taken from Customer Services Feeder Reports. Although this source permits the isolation of distinct categories such as Special Programs and provides a distinction between POE and autodin input, the 1144 demand data is undoubtedly more accurate. It would appear that some categorization by cog for provisions and certain bulk material would be possible. Therefore, consideration might be given to revising the model to accommodate categories that are identifiable on the 1144. This, of course, would be a long range goal.

The model could be improved immensely with more realistic standards for activities ranging from editing on Figure 7-5 to marking on 9-3. Every constant service time that can be replaced by a distributional assumption with a variability estimate based on observed processing times will contribute to the validity of the model. Packing estimates are particularly illustrative of the necessity for improved standards. Recently developed light and heavy pack standards are modeled as identical for Broadway bin and National City material and higher (more packs per hour) for Broadway bulk; the DIMES standards used in reference (b) are judged to be completely errroneous. Regardless of which set of standards, DIMES or locally developed, are more accurate, the overriding factor in packing is the tremendous variability in pack times. Additional time and motion studies are probably out of the question,

but all service times used in the model should be carefully reviewed with the cognizant functional area supervisors. It is possible, or perhaps probable, that this initial model version contains erroneous processing times due to the modeler's misinterpretation of the data provided. In any case, all processing times should be confirmed or, if possible, revised to include variability estimates. SHORSTAMPS program development, which purports to determine personnel requirements by function, may have contained an intermediate time-by-function calculation that is well documented and can be used to improve the model standards.

The uniform interarrival assumption for both autodin and POE input was born more out of desperation than from any exhaustive research. Time of arrival data is not readily available and, even if it were, it is hypothesized that the data analysis and subsequent goodness of fit testing would represent a major project in itself. Nevertheless, a more realistic modeling of autodin and/or POE interarrival times might very well contribute the most to model validity.

The processing of both provisions and Special Program transactions could be improved by adding the Customer Services edit function. These categories are edited in their own special sections and a definite delay, which is smaller for provisions documents, is encountered but accounted for in the model. It has also been asserted that a significant portion of the provisions input arrives via autodin as referrals from DPSC; it appears that specified large local customers such as

MCRD (Marine Corps Recruiting Depot) submit requisitions directly to DPSC. The model could readily be modified to recognize this routing and its impact of reducing DPD key-punch provisions workload.

The Special Program IPG II average daily input of 107 should be closely screened. If it is erroneous, the model should be revised. All Special Program transactions are assigned lengthy delays on Figure 7-7 to model their pricing cycle. Therefore, IPG II requisitions of this type will usually exceed the UMMIPS standard significantly. In recognition of this fact, statistics on Special Program IPG II and III transaction processing times are collected at nodes 256 (SPROGII) and 262 (SPROG3), respectively, on Figure 9-4.

The calculation of the National City heavy, light, and parcel post percentages shown on Figure 9-3 should be reviewed with the packing supervisor and revised if necessary. Chapter IX.D provided the rationale for the computation of these percentages. However, the values do not appear representative when compared to similar Broadway bulk percentages. Therefore, one or more of the assumptions listed in Chapter IX.D are probably erroneous.

Section IX.D also specified the QUICK PIC processing routine as an analytical starting point. QUICK PICs are sent to lotted material rather than high priority queues. Therefore, QUICK PIC issue statistics on Figure 9-4 should be reviewed to determine whether the processing of lotted backlog material is preventing the actual expeditious issue of QUICK PICs. If

it is, QUICK PICs should be routed to the IPG I queues where their processing will be ensured.

Finally, it was noted that no Broadway Bulk packer (Type 11 resource) was retained on the second shift, a factor that may erroneously delay IPG I material destined for shipping. Node 251, Broadway bulk IPH I interval statistics for material shipped (Figure 9-4), should be closely monitored to determine whether a second shift Broadway bulk packer/marker should be added to create more accurate IPG I interval times.

B. SUGGESTED AREAS OF ANALYSIS

In the process of developing the model and discussing current operating procedures with NSC San Diego personnel, numerous opportunities for both model expansion and the testing of alternative modeling techniques became apparent. The following model expansions, many of which were mentioned in Chapters 5 through 10, could be accomplished in the future:

- Technical.
- Purchase and nonstandard material exception processing by the demand exception unit.
- Shipping.
- Local delivery resource control.
- SERVMART Central Receiving.
- Cold storage requisition processing.
- Packing and preservation.
- Isolation of the LP and SP packing lines with a higher degree of consolidation (large customer lines by definition).

. Determination of resource costs and tradeoffs through similar resource type assignments to personnel with identical hourly wages and work capabilities.

. Programming of resource assignments based on a backlog analysis (Q-node content check) conducted in a disjoint resource control network.

. Addition of weekend autodin arrivals and a limited Saturday and/or Sunday workforce; e.g., process only IPG IIs on the weekend and measure the impact of the response time segments.

In addition, after the model has been validated and is simulating the current system satisfactorily, the following alternative processing techniques could be modeled and tested:

. The circumventing of the packing lines for approximately 40% of all binnable material.

. Elimination of local delivery staging for local delivery IPG III material through programming thearrival of material by conveyor belt for direct loading on delivery vehicles.

. The submission of IPG II transactions to the same programmed local delivery arrival process. If statistics nodes were strategically placed to measure both SSPT (Storage Site Processing Time) and THT (Transportation Hold Time), it could be determined whether the decrease in THT more than compensated for the increased SSPT.

. Incorporating a bulk material consolidation factor and determining whether time was actually being lost due to the increased heavy pack workload.

. Routing IPG Is through batch processing and directly to the warehouse for issue rather than through Customer Services for remote input.

The aforementioned changes are only a few of the processing functions and options that can be modeled and tested once the logic of the basic model is mastered.

C. CONCLUSION

Since there are no actual simulation runs being made, conclusions regarding the advantages of alternative processing procedures would be strictly hypothetical. It was noted, however, that the IPG II response time problem cited in reference (b) still exists. Adopting a common sense approach to the analysis, the following factors contribute significantly to the continuation of the problem:

. Special Program IPG II material - if the Customer Services Feeder Reports were interpreted correctly, the lengthy pricing delay experienced by this significant volume (107 per day) would represent a major detrimental impact on the IPG II aggregate response time.

. Local delivery staging procedures - prior methods, which are to be changed in conjunction with the programmed release of local delivery IPG III material, consisted of staging IPG IIs and IIIs together by UIC. Therefore, IPG IIs lost their identity as higher priority material after leaving packing. If the anticipated staging of IPG IIs

together and by delivery zone becomes a reality, response time may improve to some degree.

. Local delivery schedule - regardless of the action taken to resolve the aforementioned detrimental factors, it's apparent that the response time on many IPG II issues will continue to exceed UMMIPS standards as long as deliveries are limited to twice weekly at many zones.

The model is completely displayed on Figures 6-5, 6-6, 7-5, 7-6, 7-7, 8-2, 9-1, 9-2, 9-3, 9-4, 10-1, 10-2, 10-3, and 10-4. The most efficient method of reviewing the chapters 6 through 10 details is to make a separate set of the above figures for ease of reference. It is hoped that the considerable detail included, which was necessary to describe the Q-GERT concepts, will not hinder the reviewer's recognition of the modeling potential provided by this language and its unique illustrative feature.

The contribution of employees from both NSC San Diego and Pritsker and Associates toward the development of this model cannot be minimized. Their cooperation, knowledge, and perhaps most importantly, their patience were vital factors in the model formulation.

APPENDIX A - Q-GERT Distribution and Function Types with Required Parameter Values

Distribution and Function Types		Parameter Values*			
Code	Key	1	2	3	4
AT	Attribute	-	-	-	-
BE	Beta	μ	a	b	σ
BP	Beta PERT	m	a	b	-
CO	Constant	μ	-	-	-
ER	Erlang	μ/k	a	b	k
EX	Exponential	μ	a	b	-
GA	Gamma	μ	a	b	σ
IN	Incremental	-	-	-	-
LO	Lognormal	μ	a	b	σ
NO	Normal	μ	a	b	σ
PO	Poisson	μ-a	a	b	-
TR	Triangular	m	a	b	-
UF	User Function	-	-	-	-
UN	Uniform	-	a	b	-

* $\rightarrow$ not used; $\mu \rightarrow$ mean; $\sigma \rightarrow$ standard deviatior

m $\rightarrow$ mode; a $\rightarrow$ minimum or optimistic time;

b $\rightarrow$ maximum or pessimistic time.

APPENDIX B - NSC San Diego Daily Demand Data - October 1979 Through February 1980

Monday - 18 observations which include Saturday and Sunday input

A. ⟵ Autodin Input

4,847 IPG I + 13,649 IPG II + 15,137 IPG III = 33,453 TOTAL

Max	456	[1] 2,174	2,001	
Min	40	228	367	
Avg	269	[1] 748	841	1,858 Avg Daily Autodin Input
Std. Deviation	118.38	465.25	428	
% of Total	14.5%	40.2%	45.3%	

B. ⟵ Hot Line (Customer Services) Input

3,640 IPG I + 37,984 IPG II + 27,438 IPG III = 69,062

Max	441	3,198	2,904	
Min	51	728	440	3,836 Avg Daily Hot Line Input
Avg	202	2,110	1,524	
Std. Deviation	105.34	777.6	544.9	
% of Total	5.3%	55.0%	39.7%	

C. ⟵ Provisions Input

12,337 IPG III = 12,337 Total

Max	1,558	685 Avg Daily Provisions Input
Min	216	
Avg	685	

D. ⟵ Monday Totals

8,487 IPG I + 51,453 IPG II + 54,912 IPG III = 114,852

Avg	471	2,858	3,052	6,381 Demands Per Day
% of Total	7.4%	44.8%	47.8%	

Provisions input represents 10.7% of all demands and 22.5% of IPG III demand.
Autodin represents 29.1% of average daily demand for Monday.
Autodin represents 32.6% of average daily nonprovisions demand.

---

[1] A 14 January autodin IPG II input of 8,552 was disregarded and replaced with the average of the remaining 17 observations.

Tuesday - 20 observations

A. Autodin Input

6,587 IPG I + 13,082 IPG II + 12,165 IPG III = 31,834 TOTAL

Max	622	1,561	1,035	
Min	[1] 140	173	112	1,592 Avg
Daily Avg	[1] 329	655	608	Daily Autodin
Std. Deviation	132.05	286.5	235.88	Input
% of Total	20.7%	41.1%	38.2%	

B. Hot Line (Customer Service) Input

3,667 IPG I + 37,288 IPG II + 23,480 IPG III = 64,435 TOTAL

Max	469	3,476	2,822	
Min	44	1,032	197	3,222 Avg
Daily Avg	183	1,865	1,174	Daily Hot Line
Std. Deviation	95.5	764.7	637.16	Input
% of Total	5.7%	57.9%	36.4%	

C. Provisions Input

9,979 IPG III = 9,979 TOTAL

Max	1,457	525 Avg
Min	216	Daily Provisions
Daily Avg	525	Input

D. Tuesday Totals

10,254 IPG I + 50,370 IPG II + 45,624 IPG III = 106,248

Daily Avg	526	2,519	2,281	5,326 Demands
% of Total	9.65%	47.4%	42.95%	Per Day

Provisions input represents 9.4% of all demands and 21.9% of IPG III demand.
Autodin represents 30.0% of average daily demand for Tuesday.
Autodin represents 33.1% of average daily nonprovisions demand.

---

[1] A zero ("0") IPG I autodin input was replaced by the average of the 19 other values.

Wednesday - 21 observations

A. Autodin Input

6,322 IPG I + 13,178 IPG II + 16,551 IPG III = 36,051 TOTAL

Max	826	1,376	1,939	
Min	25	159	268	1,717 Avg
Daily Avg	301	628	788	Daily Autodin
Std. Deviation	221.4	284.2	431.9	Input
% of Total	17.5%	36.5%	46.0%	

B. Hot Line (Customer Service) Input

3,215 IPG I + 37,902 IPG II + 27,331 IPG III = 68,448 TOTAL

Max	392	3,342	2,397	
Min	56	282	269	3,259 Avg
Daily Avg	153	1,805	1,301	Daily Hot Line
Std. Deviation	85.8	728.3	536.1	Input
% of Total	4.7%	55.3%	40.0%	

C. Provisions Input

7,965 IPG III = 7,965 TOTAL

Max	944	379 Avg
Min	132	Daily Provisions
Daily Avg	379	Input

D. Wednesday Totals

9,537 IPG I + 51,080 IPG II + 51,847 IPG III = 112,464

Daily Avg	454	2,432	2,469	5,355 Demands
% of Total	8.5%	45.4%	46.1%	Per Day

Provisions input represents 7.1% of all demands and 15.4% of IPG III demand.
Autodin represents 32.0% of average daily demand for Wednesday.
Autodin represents 34.5% of average daily nonprovisions demand.

Thursday - 20 observations

A. Autodin Input

6,134 IPG I + 15,650 IPG II + 14,794 IPG III = 36,578 TOTAL

Max	505	2,009	1,176	
Min	60	335	395	1,829 Avg
Daily Avg	307	783	740	Daily Autodin
Std. Deviation	120.62	445.37	243.27	Input
% of Total	16.8%	42.8%	40.4%	

B. Hot Line (Customer Service) Input

3,051 IPG I + 31,377 IPG II + 16,590 IPG III = 51,018 TOTAL

Max	303	3,834	2,906	
Min	62	769	201	2,551 Avg
Daily Avg	153	1,569	830	Daily Hot Line
Std. Deviation	76.47	763.77	339.9	Input
% of Total	6.0%	61.5%	32.5%	

C. Provisions Input

10,987 IPG III = 10,987 TOTAL

Max	1,069	550 Avg
Min	216	Daily Provisions
Daily Avg	550	Input

D. Thursday Totals

9,185 IPG I + 47,027 IPG II + 42,371 IPG III = 98,583

Daily Avg	459	2,351	2,119	4,929 Demands
% of Total	9.3%	47.7%	43.0%	Per Day

Provisions input represents 11.1% of all demands and 25.9% of IPG III demands.
Autodin represents 37.1% of average daily demand for Thursday.
Autodin represents 41.8% of average daily nonprovisions demand.

Friday - 22 Observations

A. Autodin Input

8,215 IPG I + 14,568 IPG II + 16,051 IPG III = 38,834 Total

Max	741	1,331	1,227	
Min	24	320	238	
Daily Avg	373	662	730	1,765 Avg Daily Autodin Input
Std. Deviation	189.1	251.3	266.1	
% of Total	21.2%	37.5%	41.3%	

B. Hot Line (Customer Services) Input

3,978 IPG I + 34,315 IPG II + 23,021 IPG III = 61,314 Total

Max	352	2,662	2,911	
Min	45	661	225	
Daily Avg	181	1,560	1,046	2,787 Avg Daily Hot Line Input
Std. Deviation	75.75	556.4	690.9	
% of Total	6.5%	56.0%	37.5%	

C. Provisions Input

12,862 IPG III = 12,862 Total

Max	1,687	
Min	216	585 Avg Daily Provisions Input
Daily Avg	585	

D. Friday Totals

12,193 IPG I + 48,883 IPG II + 51,934 IPG III = 113,010

Daily Avg	554	2,222	2,360	5,136 Demands Per Day
% of Total	10.8%	43.3%	45.9%	

Provisions input represents 11.4% of all demands and 24.8% of IPG III demands.
Autodin represents 34.4% of average daily demand for Friday.
Autodin represents 38.8% of average daily nonprovisions demand.

APPENDIX C - Data Processing Department Keypunch Statistics

CATEGORY	PROVISIONS			DD 1348			SPECIAL PROGRAMS		
MONTH 1979-80	Quantity	Hours (Rounded)	#/hr (rounded) Avg hr/document	Quantity	Hours (Rounded)	#/hr (rounded) Avg hr/document	Quantity	Hours (Rounded)	#/hr (rounded) Avg hr/document
JANUARY	22,153	66	336 .0030	37,987	274	139 .0072			
FEBRUARY	17,033	45	378 .0026	32,186	234	138 .0073			
MARCH	14,767	52	284 .0035	28,353	211	134 .0074			
APRIL	17,630	50	353 .0028	39,882	274	146 .0069			
MAY	16,194	61	265 .0037	40,676	286	142 .0070			
JUNE	17,196	65	264 .0038	27,588	200	138 .0072			
JULY	15,741	60	262 .0038	34,177	235	145 .0069			
AUGUST	14,440	45	321 .0031	26,363	183	144 .0070			
SEPTEMBER	3,690	11	335 .0030	6,036	39	154 .0065			
OCTOBER	15,058	40	385 .0026	25,862	174	149 .0067	3,546	21	169 .0059
NOVEMBER	14,834	53	278 .0036	28,222	220	128 .0078	3,139	20	158 .0063
DECEMBER	15,053	41	370 .0027	20,570	156	132 .0076	3,945	25	158 .0063
JANUARY	18,389	60	306 .0033	30,208	210	144 .0069	2,877	28	103 .0097
FEBRUARY	14,668	42	349 .0029	31,858	231	138 .0073	5,985	33	181 .0055
AVERAGE	15,489/ month	49.35 hr/ month	315.3 .0032	29,283/ month	209.1 hr/ month	140.4 .0071	3,898/ month	25.4 hr/ month	153.8 .0067
STANDARD		Punch and verify→	350 .00286		Punch and verify→	150 .00667			Not Established

APPENDIX D - Model FORTRAN User Functions

```
FUNCTION UF (IFN)

1/ COMMON/QVAR/NDE, NFTBU (100), NREL (100),  NRELP (100), NREL2 (100),
  1NRUN, NRUNS, NTC (100),  PARAM (100,4), TBEG, TKNOW

UF = -NREL(INF)

RETURN

END
```

The statement UF = - NREL(INF) indicates that the value returned to the model is the negative of the number of transactions in Q-node INF. Therefore, if UF 43 were used in the network logic, the value returned would be minus the number of transactions in Q-node 43, the Customer Services keypunch queue on Figure 6-5.

1/ The COMMON statement applies for the 100 node model as indicated by the dimensioning of the various matrices. When the 1,000 node model is operational, this COMMON statement will have to be revised accordingly.

LIST OF REFERENCES

a. Pritsker, A. Alan B., Modeling and Analysis Using Q-GERT Networks, Second Edition 1979.

b. Lynch, M. G., and Ulrich, C. H., Requisition Throughput Time Simulation at Naval Supply Center San Diego, U.S. Naval Postgraduate School Thesis, March 1973.

c. NSC, San Diego, Defense Integrated Management Engineering Systems (DIMES) Methods Engineering Survey Handbooks, 1968-1970.

d. OPNAVINST 4614.1E, Uniform Material Movement and Issue Priority System (UMMIPS), 29 July 1975.

e. NSC, San Diego, Customer Services Monthly Input Feeder Reports, October 1979 - February 1980.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
3.	Department Chairman, Code 55 Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
4.	Associate Professor F. R. Richards, Code 55Rh Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
5.	U.S. Naval Supply Center San Diego, California 92132 Attn: Codes 100, 300B	2
6.	Pritsker and Associates P.O. Box 2413 West Lafayette, Indiana 47906 Attn: J. Sabuda	2
7.	Fleet Material Support Office Mechanicsburg, Pennsylvania 17055 Attn: Code 933	2
8.	LCDR Bruce R. Faurie Box 5, Code SA U.S. Naval Support Activity FPO, New York, New York 09521	4

Thesis
F2415 Faurie 190705
c.1
A Q-GERT approach to
a requisition process-
ing simulation at
Naval Supply Center
San Diego.

Thesis 190705
F2415 Faurie
c.1
A Q-GERT approach to
a requisition process-
ing simulation at
Naval Supply Center
San Diego.

thesF2415
A Q-GERT approach to a requisition proce
3 2768 001 03630 4
DUDLEY KNOX LIBRARY